TRANSACTIONS

OF

THE AMERICAN SOCIETY

OF

HEATING AND VENTILATING ENGINEERS

VOL. XIX

NINETEENTH ANNUAL MEETING

NEW YORK, JANUARY 21-23, 1913

SUMMER MEETING

BUFFALO, N. Y., JULY 17-19, 1913

PUBLISHED BY THE SOCIETY
AT THE OFFICE OF THE SECRETARY
NEW YORK CITY

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AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.

NINETEENTH ANNUAL MEETING.

Held at

Engineering Societies Building, New York City, N. Y.
January 21, 22, 23, 1913.

PROCEEDINGS.

FIRST DAY—AFTERNOON SESSION.
(Tuesday, January 21, 1913.)

The meeting was called to order at 2:30 p. m. by Vice-President John F. Hale.

Chairman Hale, having asked the Secretary if there was a quorum present and the Secretary replying in the affirmative, it was resolved on motion duly put and carried that the calling of the roll and the reading of the minutes be dispensed with.

Chairman Hale: The President being absent in foreign lands he has kindly sent us his annual address, and after a few preliminary remarks I will take pleasure in reading it.

It is nineteen years ago since the first meeting of this Society was held, and it is with a great deal of satisfaction that I welcome you to this the Nineteenth Annual Meeting of the American Society of Heating and Ventilating Engineers.

During the year 1912 the duties of the office of President have been thrown upon me, owing to the absence of President Allen in foreign lands, an undertaking I would not have been willing to assume were it not for my personal regard for Professor Allen and my deep interest in the Society's welfare.

It has been rather an arduous task to carry on the business of the organization, knowing full well that any unwise act upon my part would reflect upon another, and for that reason there have been left undone things that would otherwise have been carried to a finality.

Shortly after the announcement last year of the result of the election a letter was received from the President, stating that he believed it would be best for him to resign, as he could not personally help in the administration. But upon assurance that the officers would undertake the work in his name he was willing to remain in the position to which he had been elected. The officers who have been active in the Society's affairs feel that progress has been made during the last twelve months, and we are gratified by the expressions of approval offered as a result of the successful meeting held in Detroit last summer.

The papers and topics of discussion for this meeting will, without doubt, be entered into by those present with as much interest as in those of the past, and we hope that all will go back to their homes with the feeling that their time has been well and profitably spent.

A letter received recently from President Allen states that his paper was written during one of the battles in the war between Turkey and the Balkan States, and they could constantly hear the roar of the Bulgarian guns, so really it is remarkable that he should be able to turn out as excellent a paper as this under the circumstances.

With your permission I will read the President's address in his name.

President's address read by Vice-President Hale.

The paper was discussed by Mr. Barron and Professor Kent.

Chairman Hale then called for the report of the Secretary, which was read by Secretary Macon.

REPORT OF THE SECRETARY.

Your Secretary for the Society year ending January 21, 1913, begs to submit the following report:

The most apparent activities of the Society's headquarters this year have been the production of two volumes of proceedings in

one year; the issuance of a booklet intended to assist in the matter of campaigning for new members; the year book or directory in new form with new features, and the supply to the members of a voluminous amount of heating and ventilating literature. As regards the considerable number, size and character of the contributions to the two meetings of 1912, the Secretary feels that the Society is greatly indebted to the authors, many of whom gave results involving considerable labor, but it is felt that the merits of these contributions will be more apparent when the volume for 1912 is issued. The general editing for both the last annual and summer meeting has been completed, and it remains only to prepare the copy for the compositor, and to arrange for the additional illustrations before the matter is sent to press. The Secretary himself feels highly grateful to the many who assisted in the remarkable triumphs of the two meetings.

The financial showing for last year is submitted on the following page.

PER CAPITA EXPENSE FOR SIX YEARS

Year	Mean Number of Members	Total Expenses	Expense per Member
1907	301	$3,662.45	$12.20
1908	335	4,025.84	12.00
1909	357	4,687.41	13.13
1910	377	4,269.83	11.36
1911	405	4,793.08	11.83
1912	437	5,013.19	11.47

STATEMENT OF INCOME AND OUTGO

Cash on hand, January 25, 1912			$1,397.41	
Receipts				
Dues		$3,600.41		
Initiation fees		795.00		
Sale of Transactions, net:				
Vol. 1	$5.00			
" 2	5.00			
" 3	5.00			
" 4	5.00			
" 5	5.00			
" 6	5.00			
" 7	5.00			
" 8	5.00			
" 9 ($10-5)	5.00			
" 10 ($10-5)	5.00			
" 11 ($10-5)	5.00			
" 12 ($10-5)	5.00			
" 13 ($10-5)	5.00			
" 14 ($10-5)	5.00			
" 15 ($27.50-5)	22.50			
" 16 ($107.50-12.50)	95.00			
" 17 ($67.50-60)	7.50			
" 18	7.50			
" 19	15.00			
		$217.50		
Badges, Pin:				
Solid gold	$54.50			
Plated	10.00			
		$64.50		
Interest on deposits		30.99		
			$4,717.40	
				$6,114.81

STATEMENT OF INCOME AND OUTGO—*Continued*

DISBURSEMENTS

Transactions:					
Vol. 16 editing		$125.00			
printing, etc		1,019.10			
			$1,144.10		
Vol. 17 editing		$125.00			
extra cuts		9.55			
			134.55		
Vol. 18 engravings		$274.58			
electros sold ($50.65-7.36)		43.29			
			231.29		
Directory of Members, 1912		$147.50			
sale of		2.00			
			145.50		
Solid gold pin badges purchased			60.00		
Meetings expense:					
Advance papers	$574.90				
sale of	73.05				
		$501.85			
Stenographer		250.00			
Meeting rooms, printing, etc		277.40			
Cut of map of N. Y		4.56			
Badges—registration		60.00			
			1,093.81		
Postage, expressage, etc			287.73		
General administration:					
Salaries		$1,124.00			
Assessments (Rent) for office		396.00			
Office stationery and supplies		60.10			
New furniture, typewriter, etc		93.75			
Storage		30.50			
General printing		30.50			
Ballots		167.50			
Telephone		48.70			
Committees		17.50			
Cuts for general circulars		4.50			
Exchange		3.16			
			$1,976.21		
				$5,073.19	
Cash on hand January 21, 1913				1,041.62	
					$6,114.81

It is noted on the accompanying second table that the outgo per member is now $11.47 for the year just closed, a reduction of 3 per cent. from last year, but still unsatisfactorily high when it is realized that the income per member is $10, once initiation fees are paid.

The lateness of the receipt of papers for the present meeting has interfered with the cherished hope of the Secretary that all papers might be sent considerably in advance of the meeting, not alone to the members, but to those who might be specially invited to take part in the discussion, because of special knowledge on the subjects. It is well worth while to emphasize, however, that the papers after being sent to the members, may be discussed in writing, while the author will have his prerogative of closing the discussion before the information is arranged for the annual volume of proceedings.

Finally, may be found tables, covering the financial condition as regards dues and initiation fees accounts.

STATUS OF DUES ACCOUNT

Cr.			
In arrears, inc. portion of class of candidates elected Dec., 1911	$1,195.00		
Class of candidates, Jan., 1912, 13 at $10	130.00		
Paying members, Jan. 25, 1912, 422-13 at $10	4,090.00		
Class of candidates, June 4, 26 at $10	260.00		
Class of candidates, Dec. 19, 25 at $5	125.00		
Reinstated members, back dues	90.00		
Overpayment, account foreign exchange	1.37		
		$5,891.37	
Dr.			
Prepayment dues, 1912 account in 1911	$7.50		
Written off by death and resignation	140.00		
Written off by non-payment of dues	490.00		
Written off by failure to qualify	20.00		
Underpayments, account of foreign exchange	1.46		
Total dues received	3,609.41		
		$4,268.37	
Dues outstanding			$1,623.00

STATUS OF INITIATION FEES ACCOUNT

Cr.			
In arrears, inc. portion of candidates elected Jan., 1912	$250.00		
Class of candidates, June 4	375.00		
Class of candidates, Dec. 19	360.00		
Fee of advancement from junior grade	5.00		
		$990.00	
Dr.			
Total initiation fees received	$795.00		
Written off by failure to qualify	30.00		
		825.00	
Fees outstanding			165.00
			$1,788.00

RECAPITULATION

Total debit accounts of members	$1,800.00
Total credit accounts of members	12.00
	$1,788.00

Respectfully submitted,

W. W. MACON,
Secretary.

Chairman Hale: Gentlemen, you have heard the Secretary's report. What is your pleasure in regard to it? Have you any remarks to make on it? If not we will accept it as it stands. Do I understand, Mr. Secretary, that the Treasurer will make a report in addition to this? Secretary Macon: Yes.

Chairman Hale: We will have Mr. Donnelly give us a report of the financial condition of the Society as Treasurer.

Mr. Donnelly: Gentlemen, the Treasurer's report can hardly be more than the Secretary has given concerning the money received and paid out. The books of the Treasurer really only give the general receipts and disbursements, having nothing to do with the distribution of the accounts nor with the authorization. The method of paying bills has been the same in the past year as in previous years, which is a method which might be improved upon to some extent. For instance, the Secretary has in

his accounts or books no vouchers to retain or show by what authority any money has been paid out. It would seem as if something should be given to retain so that he would have proof of having paid out money by due authority of the Finance Committee or of the Board of Directors. There is also very little check, if any, on paying a bill twice in error, and we know how often this occurs in general business. It is better to receive payment for a bill twice and be able to return it, than to pay one out twice. But the subject of this matter I made a communication of to the Board of Directors last fall, and they recommended to the next Board of Directors that a change be made in the method of keeping vouchers.

I do not know anything that the Treasurer can add to this, except that I have put the money in the bank as it was received and paid the bills as promptly as they were sent in.

Chairman Hale: I will state that the remarks made by Mr. Donnelly with reference to the modifications in our methods have been taken up or will be taken up in the report of the Board of Governors, and the points referred to I think will be covered. The Board of Governors have made a report and I will ask the Secretary to read it as he has it for that purpose.

REPORT OF THE BOARD OF GOVERNORS.

The Board of Governors makes the following report of the activities of the Society since the organization of the Board, January 24, 1912, immediately following the last annual meeting.

The Board has maintained headquarters in the Engineering Societies Building, 29 W. Thirty-ninth Street, New York City, and the office of the Secretary has been used to a greater extent than before by the individual members and by committees for meeting purposes. In this connection, the Board feels that special recognition should be taken of the petition offered to the previous Board of Governors early in 1911 by 12 members offering to raise the money necessary to maintain the Society's headquarters in the Engineering Societies Building, as it then seemed that some difficulties might arise in providing for the extra amount of money which such a departure might entail. The experience of the last two years has abundantly proved the wisdom of the choice and of the Society's ability to maintain its headquarters in

a building so admirably adapted to its use and so specially identified with the engineering profession in its largest aspect. It has not yet, nor is it likely that the Society will ever ask for this proffer of funds, and it is here officially declared that the petitioners are relieved of their self-imposed obligation, and that this special record is to be taken as a token of appreciation on the part of the Board.

Among the notable events of the past year is to be mentioned the summer meeting of 1912, held in Detroit, Mich., July 11 and 12. The meeting was remarkable for the volume and character of the technical contributions, and for the admirable entertainment arrangements which had been made by the Detroit members.

The Board had the pleasure of approving an application from and approving the By-laws of the Massachusetts Chapter, centered in Boston, and is glad to take cognizance of the suggested formation of a Chapter with headquarters in Philadelphia. The Board feels that it is altogether in order to express a word of encouragement toward the establishment of Chapters, which have proved advantageous to a local group through opportunity to congregate periodically, and to exchange information more or less informally—a practice which has already proved of permanent benefit to the progress of the Society itself.

Some of the side lights indicating the degree of interest in the Society are obtained, for example, through the attendance at the summer meeting, and the percentage of members voting on mail ballots. At the Detroit meeting, about 9 per cent. of the membership was present, and the guests numbered two for every member, a ratio calculated to show a growing interest of nonmembers toward affiliation. As regards the vote on the proposed changes to the by-laws, no less than 34.3 per cent. of the voting strength was polled, and the by-laws were adopted by a large majority over the necessary two-thirds.

The financial reports are dealt with in the reports of the Secretary and Treasurer. While the outgo for each member is still considerably greater than the amount of dues from the member, and the Society is still maintaining solvency through the use of initiation fees, the per capita cost has been reduced in spite of a large increase in the number of pages of technical information already supplied to the members, as compared with former years. It is still clear that a decided increase in membership is needed if

the scale of recent operations is to be continued without impairing the financial status.

It might here be stated, as a matter of general record, that the auditing committee, appointed at the beginning of this last year to audit the books of the Secretary and the Treasurer, found them correct. The reports of both the Secretary and the Board of Governors for 1911 were mailed to members early in 1912.

The Board held eight meetings during the year, and its deliberations in detail will be found in the Society records. The Society was represented in other meetings, and in committee work with other Societies as follows: Nelson S. Thompson, at the International Congress on Hygiene and Demography, Washington, D. C., September 23-28; D. D. Kimball was appointed chairman of the section on ventilation in the department of Industrial Hygiene and Sanitation of the American Museum of Safety, New York; S. R. Lewis, J. H. Davis, N. L. Patterson, Theodore Weinshank and Joseph G. Hayes were appointed to represent the Society at the National Conservation Congress, Indianapolis, Ind., October 1-4; James D. Hoffman represented the Society at the International Congress for Testing Materials, New York, September 2-9; E. F. Capron, D. M. Quay, W. F. Devendorf, M. L. Foote and W. C. Green were appointed a committee to confer with the National District Heating Association.

A notable gift was made to the Society by Dr. Wm. Paul Gerhard, C. E. This comprised 91 books and pamphlets on heating and ventilation in the English and German languages, and is here listed. These volumes have been installed in the Society's library, and it is desired that the Society, at its annual meeting, shall take special recognition of the bequest, which will undoubtedly be very highly appreciated, particularly as it affords the individual member an opportunity to consult books, many of which are rare.

LIST OF BOOKS DONATED BY DR. WM. PAUL GERHARD.

IN ENGLISH.

Air and Life, by Henry de Varigny. (Smithsonian collection. Government Printing Office, Washington, D. C., 1896.)

Air We Breathe, The, by H. A. Mott, Jr. John Wiley & Sons, 1883.

Arid Atmosphere of Our Houses in Winter, The, by Dr. H. J. Barnes. (Reprint, American Public Health Association.) Rumford Press, Concord, N. H., 1898.

Atmosphere in Relation to Human Life and Health, by F. A. R. Russell. Smithsonian Institution, Washington, D. C., 1896.

Essay on Heating and Ventilation of Public Buildings, by J. L. Smithmeyer. R. O. Polkinhorn & Son, Washington, D. C., 1886.

Explorations of the Upper Atmosphere, by Henri de Graffigny. (Smithsonian Report.) Government Printing Office, Washington, D. C., 1898.

General Circulation of the Atmosphere, by Werner von Siemens. Smithsonian Institution, Washington, D. C., 1893.

Gouge on Ventilation, by Henry A. Gouge. D. Van Nostrand, New York, 1881.

Health and Comfort in House Building, by J. Drysdale and J. W. Hayward. E. & F. N. Spon, London, Eng., 1876.

Heating and Ventilating of Residences, by James R. Willett. Address delivered before the University of Illinois, 1893.

Heating and Ventilating of State House, Augusta, Me., by S. H. Woodbridge. Report State Board, Maine, 1889.

Heating by Hot Water, by Walter Jones. Crosby Lockwood & Son, London, Eng., 1890.

Helios. Heine Safety Boiler Co., St. Louis, Mo., 1893.

Hot Water Heating and Fitting, by W. J. Baldwin. *Engineering & Building Record,* New York, 1889.

Hot Water Heating Illustrated. *Metal Worker,* New York, 1889.

House Chimneys. *Metal Worker,* New York, 1901.

Manual of Heating and Ventilation, by F. Schumann. D. Van Nostrand, New York, 1886.

Method of Heating, Lighting and Ventilating the Hall of the House of Representatives. Report, Washington, D. C., 1884.

Modern House Heating. Gorton & Lidgerwood, New York, 1891.

Natural and Artificial Methods of Ventilation. Robert Boyle & Son, London, Eng., 1899.

Natural Ventilation. *Building News,* 1899.

Non-Conducting Coverings for Steam Pipe, by Prof. J. M. Ordway. American Society of Mechanical Engineers, Vol. 5.

Practical Sanitary Science, Parts 1 and 2, by W. H. Maxwell. Sanitary Publishing Co., Ltd., London, Eng., 1897.

Practical Treatise on Ventilation, by Morrill Wyman. J. Munroe & Co., Boston, Mass., 1846.

Practical Ventilation, by R. S. Burn. William Blackwood & Sons, London, Eng., 1850.

Properties of Air Relating to Ventilation and Heating, by Robert Briggs. (Reprint, Franklin Institute.) Merrihew & Lippert, Philadelphia, Pa., 1881.

Progress of Natural Ventilation. *Building News,* 1901.

Relations of Air and Water to Temperature and Life, by G. G. Hubbard. (Smithsonian Report.) Government Printing Office, Washington, D. C., 1894.

Relation of Moisture in Air to Health and Comfort, by Robert Briggs. Journal of Franklin Institute, Philadelphia, Pa., 1878.

Relative Economy of Ventilation by Heated Chimneys and Ventilation by Fans, by W. P. Trowbridge. American Society of Mechanical Engineers, Vol. 7.

Report on the Holly District System of Steam Heating, by Gen. Herman Haupt. Union Printing & Pub. Co., Lockport, N. Y., 1879.

Rival Systems of Heating, by A. N. Bell and W. P. Trowbridge. Extracted from a number of the *North American Review* (no date).

Steam. Babcock & Wilcox Co., New York, 1904.

Steam and Hot Water Heating for Warming and Ventilating All Kinds of Buildings. Swamscot Machine Co.

Steam Heating for Buildings, by W. J. Baldwin. John Wiley & Sons, New York, 1883.

Smoky Chimneys, by Capt. J. T. Johnston. Bowering & Co., Plymouth, Eng., 1883.

Some Whys, Whats and Hows of Ventilation, by S. H. Woodbridge. Vermont State Board of Health Bulletin, Brattleboro, Vt., 1904.

Theory and Designs of Chimneys, by H. B. Gale. American Society of Mechanical Engineering, Vol. XI.

Unwise Heating Contracts. *Engineering Record*, 1894.

Upward Versus Downward Ventilation (extract from report on ventilation of the Capitol, Washington, D. C.), by Prof. S. H. Woodbridge. R. Boyle & Sons, London, Eng., 1900.

Useful Hints on Ventilation, by W. Walker. Simpkin, Marshall & Co., London, Eng., 1850.

Ventilation and Warming of School Buildings, by Gilbert B. Morrison. D. Appleton & Co., New York, 1887.

Ventilation, by W. P. Buchan. Crosby, Lockwood & Co., London, Eng., 1891.

Ventilation, by L. W. Leeds. John Wiley & Son, New York, 1876.

Ventilation and Heating, by Dr. J. S. Billings. *Sanitary Engineer*, New York, 1884.

Ventilation and Warming, by A. N. Bell. *The Sanitarian*, 1884.

Ventilation in American Dwellings, by D. B. Reid. John Wiley & Sons, New York, 1864. (Contains also introductory outline of the progress of improvement in ventilation, by Elisha Harris.)

Ventilation of Halls of Audience, by Robert Briggs. American Society of Civil Engineers, 1881 (2 copies).

Ventilation of the Hall of the House of Representatives. Report, Washington, D. C., 1878.

Ventilation of the Hall of the House of Representatives. Report, Washington, D. C., 1884.

Warming and Ventilation, by Charles Tomlinson. Crosby, Lockwood & Co., London, Eng., 1878.

IN GERMAN.

Bau der Feuerungsanlagen, Der, Heft IV, Dampfkessel, u. s. w.; Heft V. Heizungen, von W. Jeep. Karl Scholtze, Leipzig, Germany, 1876.

Central Dampfheizung und maschinellen Einrichtungen der Rheinischen Provincial Irrenanstalten, von Marnitz. A. Seydel, Berlin, 1879.

Centralluftheizungsanlagen ohne beiordnung von Centrifugal-ventilatoren, von Otto Wuttke. A. Seydel, Berlin, Germany, 1879.

Elemente der Lüftung und Heizung, von F. Fanderlik. Carl Graeser. Wien, Austria, 1887.

Feuerungsanlagen für Häusliche und Gewerbliche Zwecke, von Dr. Ferd. Fischer. J. Bielefeld's Verlag, Karlsruhe, Germany, 1889.

Frage der Ventilation mit Beschreibung des "minimetrischen" Apparates zur Bestimmung der Luftverunreinigung, von Dr. George Lunge. Cäsar Schmidt, Zurich, Switzerland, 1879.

Grundsätze zur Erwärmung Geschlossener Räume, Darlegung der, von W. Mehl Dresden. F. Leineweber, Leipzig, Germany, 1903.

Handbuch der Ventilation und Heizung, von Ludwig Degen. J. Lindauer'-sche Buchhandlung, München, Germany, 1878.

Heisswasserheizung, Theorie der, von J. Einbeck. Konrad Wittwer, Stuttgart, Germany, 1887.

Heiz- und Ventilationsanlagen in den städtischen Schulgebäuden zu Darmstadt, Untersuchungen der, von Arnold Bergsträsser, Darmstadt, 1880.

Heizmaterialien, von G. K. Strott. C. C. Müller'sche Buchhandlung, Holzminden, Germany, 1876.

Heizung, Beleuchtung und Ventilation, Katechismus der, von Th. Schwartze. J. J. Weber, Leipzig, Germany, 1884.

Heizungs- und Lüftungs Einrichtungen des Eisenwerks Kaiserslautern. A Seydel, Berlin, Germany, 1887.

Heizungs-Technik, von J. Einbeck. Hermann Risel & Co., Hagen, W., Germany, 1886.

Heizungs-, Ventilations- und Trocken-Anlagen sowie Dampf- Koch-, Wasch- und Bade Einrichtungen, von A. Hausding. A. Seydel, Berlin, Germany, 1884.

Heizung und Lüftung, von Ed. Deny. Ernst & Korn, Berlin, Germany, 1886.

Heizung und Lüftung, von W. L. F. Moltrecht. Bonness & Hachfeld, Potsdam und Leipzig, Germany.

Heizung und Lüftung von Gebäuden, von Anton Gramberg. Julius Springer, Berlin, Germany, 1909.

Heizung und Ventilation, von K. Ulmi. E. W. Krebs, Berne, Switzerland, 1883.

Heizung und Ventilation in Fabrikgebäuden und die Einrichtung von Trocknungs-Apparaten, von C. Schinz. Baumgärtner's Buchhandlung, Leipzig, Germany, 1882.

Hilfstabellen zur Berechnung von Warmwasserheizung, von H. Recknagel. R. Oldenbourg, München and Berlin, Germany, 1909.

Hochbau- Konstruktionen, von Rudolph Gottgetreu. Ernest & Korn, Berlin, Germany, 1888.

Kohlenoxydes in sehr Kleinen Mengen und Einige Bemerkungen zu der sogenannten Luftheizungsfrage, von Dr. Friedrich Gottschalk. Johann Ambrosius Barth, Leipzig, Germany, 1877.

Lehre von Luftwechsel, von Dr. Gustav Wolffhügel. R. Oldenbourg, München, Germany, 1893.

Leitfaden zum Berechnen und Entwerfen von Lüftungs und Heizungs-Anlagen (I and II), von H. Rietschel. Julius Springer, Berlin, Germany, 1893.

Leitfaden zum Berechnen und Entwerfen von Lüftungs und Heizungs-Anlagen (I and II), von H. Rietschel. Julius Springer, Berlin, Germany, 1909.

Luft in Versammlungssälen, Schulen und in Räumen für öffentliche Erholung und Belehrung, von Th. Oehmcke. R. Oldenbourg, München, Germany, 1901.

Luft und Lüftung ver Wohnung und verwandte Fragen, von Th. Oehmcke. R. Oldenbourg, München und Berlin, 1904.

Lüftungsanlagen, von F. H. Haase. J. G. Cotta'schen Buchhandlung, Stuttgart, Germany, 1893.

Natürliche Ventilation und die Porosität von Baumaterialien, von C. Lang. Meyer & Zeller, Stuttgart, Germany, 1877.

Natürliche Ventilation vermittels des selbsttätigen luftventils, von Otto Wuttke. Langenscheidt'schen Buchdruckerei, Berlin, 1881.

Ofen der Zukunft, Der, von Karl Lerch. Spielhagen & Schurich, Wien, Austria, 1886.

Prüfung von Ventilations-Apparaten, von Gustave Wolffhügel. E. Mühlthlaler, München, Germany, 1876.

Technologie der Wärme, Feuerungsanlagen, Kamine, Oefen, Heizung und Ventilation der Gebäude, von Rinaldo Ferrini. Herman Costenoble, Jena, Austria, 1878.

Ventilations-, Beleuchtungs- und Beheizungs-Anlage im. kgl. Odeon in München, von Lothar Diehl. Theodor Riedel, München, Germany, 1887.

Ventilation Landwirthschaftlicher Gebäude, von Karl Möder. Bernhard Friedrich Voigt, Weimar, Germany, 1867.

Ventilation und Disinfection der Wohnräume, von G. K. Strott. C. C. Müller'sche Buchhandlung, Holzminden, Austria, 1876.

Warmluftheizung- mit continuirlicher Feuerung, von G. Lasius. Orell Füssli & Co., Zurich, Switzerland, 1880.

Was sollen wir brennen? von A. von Fragstein. Rudolph Lincke, Leipzig, Germany, 1884.

Werth der Ventilation, von Dr. Krieger. Ludolf Beust, Strassburg, Germany, 1899.

Zimmerluft Ventilation und Heizung, von Dr. Carl Munde. Arnoldische Buchhandlung, Leipzig, Germany, 1877.

STATUS OF MEMBERSHIP

Honorary Members				3	
Members:					
Total number January 25, 1912			382		
Accessions by election	31				
by reinstatement	2				
by advancement from junior grade	1				
		34			
Losses by resignation	8				
by non-payment of dues	12				
by failure to qualify	1				
by death	5				
		26			
Net increase			8		
Total number members, January 21, 1913				390	
Associate Members:					
Total number, January 25, 1912			27		
Accessions by election	14				
by reinstatement	1				
		15			
Losses by resignation	1				
by non-payment of dues	2				
by failure to qualify	1				
		4			
Net increase			11		
Total number, January 21, 1913				38	
Junior Members:					
Total number, January 25, 1912			13		
Accessions by election	6				
Loss by advancement to member	1				
Net increase			5		
Total number, January 21, 1913				18	
					449
Total membership, January 21, 1913					449
Total membership, January 25, 1912					425
Net total increase					24

The details in the changes in membership are shown in the accompanying summary. Two ballots were canvassed in the usual manner, on June 4 and December 19. There were 27 candidates on the first ballot, of which number one failed of election; there were 27 candidates on the second ballot, of which number two failed of election. The reinstatements for the year amounted to 3, making a gross increase of 54. There was an absolute loss of 30, as shown, making a net gain of 24.

A most trying character of loss is that which had to be recorded this year, namely, the failure of two candidates to qualify for membership, after continued forbearance on the part of the officers.

The Society suffered the loss of four members by death this year, and one other, whose demise was reported too late to be included in last year's statements. The list includes a past President and also a charter member. The officers have already taken the initial steps toward expressing sympathy toward the members of the families of the deceased, and it is here urged that in the volume of proceedings for 1912 biographical sketches be incorporated, so that there may be a lasting record of the career and achievements of the departed members, who are as follows: Warren S. Johnson, Los Angeles, Cal., who joined the Society in 1906, and who died December 5, 1911; W. C. Bryant, who joined the Society in 1901, and who died April 6, 1912; Herbert A. Joslin, who joined the Society in 1896, and who died October 3, 1912; Andrew Harvey, a past President, who joined the Society in 1896, and who died October 9, 1912; and Newell P. Andrus, a charter member, who died January 13, 1913.

Those who were honorably withdrawn from membership, because their resignations could be accepted, were Frank W. Foster, Boston, Mass.; Louis D. Collins, Geneva, N. Y.; J. G. Klemme, Philadelphia, Pa.; J. G. Eadie, Bayonne, N. J.; J. J. Tait, San Francisco, Cal.; N. L. Danforth, Buffalo, N. Y.; A. T. Kellogg, Francitas, Texas; H. H. Ritter, New York City, and W. C. J. Doolittle, Utica, N. Y.

Of other losses in membership, it is perhaps unethical to name those who were dropped for non-payment of dues.

Finally, the Board desires to make a number of recommendations:

1. That the incoming Council institute an investigation into

the status of the present by-laws in relation to the membership corporation law of the State of New York.

2. That steps be taken to amend the by-laws, so that the report of the nominating committee shall be placed in the hands of the Secretary 90 days in advance of the annual meeting, so that plenty of time shall be given for publicity to the nominating committee's report, and the opportunity be made available for independent nominations prior to the time when the ballots should be presented to the membership, namely, 60 days before the annual meeting, as stipulated in the by-laws.

3. That for its financial reports the business year range from January to January, so that there can be plenty of time for the proper closure of the books and preparation of reports as well as an investigation of the accounts by the auditing committee prior to the annual meeting.

4. That an applicant for membership be not given the opportunity to state the grade of membership he desires to enter, so that the membership committee and the Council may place the applicant in the class to which he belongs, and that time may be saved in preparing ballots for voting.

5. That the incoming Council consider the desirability of establishing a voucher system of checks for making the Society disbursements.

Respectfully submitted for the Board by

JOHN F. HALE, *Acting Chairman.*
W. W. MACON, *Secretary.*

Chairman Hale: Gentlemen, are there any remarks you wish to make in reference to this report of the Board of Governors?

Mr. Donnelly: Mr. President, there is one thing I think ought to be added to that report of the Board of Governors. The law calls for the filing of a list of the personal property or all property owned by the Society or membership corporations, stating where it is located. It seems as if this might easily be done and it should be filed in the county clerk's office.

Chairman Hale: Possibly that might be covered by the paragraph in reference to the investigation of our relations.

Mr. Donnelly: I was thinking that this work could be done this year, and it should be started and done as quickly as possible.

Mr. Chew: As you all know, we have heard three reports, one, of the Secretary, the Treasurer, and the Board of Governors; and one thing appeals to me very strongly, and I think also to the men of business, and that is that about fifteen per cent of our income is lost every year through non-payment of dues; if it is not fifteen per cent, then some other percentage close to this figure; and fifteen per cent in some kinds of business is a fair profit. Hence I think that this subject is of sufficient importance to give a little consideration to before we accept the report.

The Secretary has read the names of those who thought enough of themselves and of the Society to hand in their resignations while they were yet in good standing. The first article in the constitution says the objects shall be, among other things, the maintenance of a high professional standard among its members. I do not know whether it is a very high professional standard to say to the other members, "I don't think enough of the Society to pay my obligations." I do not know just how you can bring such a man to see the error of his ways; but when we lose as much as $400 or $500 every year in dues it is too considerable an item to pass without some notice being taken of it and some effort being made to prevail upon delinquent members to meet their obligations to the Society.

Secretary Macon: I think it is only fair to say that in connection with those members who have been dropped out for nonpayment of dues, that action is only taken by the Board of Governors after repeated attempts to get them to pay up by writing them the nicest letters we know how, but in most cases getting absolutely no reply.

Chairman Hale: In accordance with the Constitution and By-laws it is necessary for the Chair to appoint a committee to count the ballots of election. I therefore appoint Mr. Frederick K. Davis, Mr. Edward K. Munroe and Mr. U. G. Scollay a committee of three to count the ballots deposited in the election which has just taken place and to report at this meeting, if possible, the results.

The books of the Treasurer must now be audited and I ask Mr. Chew, Mr. Timmis and Mr. James H. Davis to audit the books of the Society and report to the Chair before this meeting is over.

By mistake on the part of the Chairman he omitted to call for the reports from our three Chapters, and they will be received now. I ask Mr. Lewis, of the Illinois Chapter, to read the report of their proceedings during the past year.

Mr. Lewis: This is a report of the Board of Governors of the Illinois Chapter for the year 1912-1913.

REPORT OF THE BOARD OF GOVERNORS OF THE ILLINOIS CHAPTER.

The first meeting of the Illinois Chapter was held on October 14, in the banquet room, Vogelsang's Restaurant. This was the regular annual meeting, and the following officers were elected:

J. M. Stannard, President.
George H. Getschow, Vice-President.
Will L. Bronaugh, Secretary.
August Kehm, Treasurer.
Board of Governors—S. R. Lewis, R. A. Widdicombe, L. C. Soule.

At the same time, William Lees, of Chicago, was elected to full membership; H. K. Lees and J. E. Miller, Junior Members.

A communication from Dr. Hill, the new Inspector on Ventilation of the Department of Health, was read, in which he appealed to the Society for its coöperation in the enforcing of the ordinances for ventilation. It was then determined to devote the next regular meeting of the Society to a discussion on the ventilation of small theaters; Mr. Hogan, Mr. Truitt and Mr. Schaefer being appointed to serve on this committee, and that Dr. Hill, Mr. Ball and Dr. Young be invited to be present.

It was also determined at this meeting that postal cards be sent to the various members for suggestions as to suitable topics for discussion for the new year. This was carried out on the part of the Society and brought forth quite a number of good, pertinent suggestions. A consideration of these topics on the part of the Board of Governors enabled them to select the topics for the year and assign the committees in charge of the meetings as follows:

October 14, 1912.—Election of officers, installation of new officers and organization.

November 11, 1912.—"The Heating and Ventilation of Small

Theaters." E. L. Hogan, Chairman; Cuthbert Schaefer, J. E. Truitt.

December 9, 1912.—"Heating and Ventilating." R. B. Hayward, Chairman; James H. Davis, A. H. Schroth.

January 13, 1913.—"Conditioning of Feed Water," oil, corrosion, scale, odor. With papers written by experts on water softening, dealing with the elimination of scale in boilers, and whether steam or vapor passing into rooms from air vents is detrimental to the best sanitary conditions or not. John D. Small, Chairman; Charles F. Newport, W. B. Graves.

February 10, 1913.—"Expense of Operating, Heating and Ventilating Plants," power, fuel, etc. Methods of computing operating cost in advance of construction, etc. H. M. Hart, Chairman; N. L. Patterson, G. W. Hubbard.

March 10, 1913.—"Ventilation, Progress of the Tests at the Experimental Room at the Chicago Normal School," by F. W. Shepherd. Report on "Progress of Compulsory Ventilation Laws," by Dr. Evans. J. H. Kassa, Chairman; H. W. Ellis, George H. Kirk.

April 14, 1913.—"The Heating and Ventilation of Large Manufacturing Plants." General discussion and plans of a number of unique installations. August Kehm, Chairman; W. A. Pope, R. M. Stackhouse.

May 12, 1913.—Subject and committees to be announced later. Possibly a social meeting with prominent speakers. Reports of officers, etc.

The next regular meeting was held on November 11, and the topic was the "Ventilation of Small Theaters." This brought forth quite an interesting discussion, together with a number of plans. There were about forty-five present at this meeting.

On account of the revising of the parent body by-laws it was necessary to revise the by-laws of the local chapter, and a committee was duly appointed for this purpose. The revised draft of the by-laws was submitted to the Board of Governors and read over carefully at the meeting held on November 19.

At this meeting, the President appointed the new committee to coöperate with the Health Department in consideration of "Ventilation" problems; and also, a committee to coöperate with Dr. Young toward getting the City Council to allow finances for a continuance of the "Ventilation" Department.

The next regular meeting was held on December 9. The Auditing Committee reported an examination of the Treasurer's books, showing a balance on hand of $493.87 on November 15. This committee took occasion to compliment the Treasurer on the manner in which the books were kept.

At this meeting, Professor Busey, of Buffalo, New York, gave an illustrated talk on "Air Washers and Humidifiers," being a most interesting and instructive meeting.

The spirit among the members of the Chapter seems to be one of progress, and much enthusiasm is manifested over the results being accomplished—and there seems to be a concerted desire toward increasing the membership.

W. L. Bronaugh,
Secretary.

Chairman Hale: You have heard the report of the Illinois Chapter. Are there any remarks? If there are not we will accept it and place it on our records.

Chairman Hale: I ask the New York Chapter to make their report at this time.

REPORT OF THE NEW YORK CHAPTER.

The New York Chapter of this Society desires to make the following report:

A detailed report of the work of the Chapter, covering the months of January, February, March, April and May, was made at the summer meeting of the Society.

The Chapter held its annual meeting on Tuesday, October 15, in the Engineering Societies Building, when the newly-elected officers were installed.

The following officers were elected for the ensuing year:

President, F. G. McCann.
Vice-President, D. D. Kimball.
Secretary, Joseph Graham.
Treasurer, Arthur Ritter.

Board of Governors—W. M. Mackay, Conway Kiewitz, W. W. Macon.

The topic, "The Relative Efficiency of Wrought Iron Pipe Coils and Cast Iron Pipe Surface for Indirect Heaters," was discussed.

The committee on "The Ventilation of Motion Picture Show Places" reported progress. It was decided to enlarge the scope of this committee to cover theaters where motion pictures are produced, as well as the ordinary motion picture show places.

An interesting evening was spent at the November meeting in discussing the heating and ventilating features of the proposed Ohio State Building Code, which were brought before the Chapter by Mr. D. D. Kimball.

The December meeting was one of the best attended of the year, at which time Mr. Arthur K. Ohmes gave a talk on "The Interesting Features of the Heating and Ventilating Plant of the Hotel St. Regis, New York."

W. W. Macon, Secretary of the Society, announced that the Board of Governors of the Society had referred to the Chapter a letter from W. A. Prendergast, Controller of the City of New York, asking for assistance in standardizing salaries for engineering services performed for the City of New York.

This matter was referred to the Committee of the Chapter on Fees for Engineering Services.

The January meeting was held on the fourteenth, at which time the report of the Committee on the Ventilation of Motion Picture Show Places was made by Chairman Frank T. Chapman.

A report was made by Frank K. Chew on the trip which the members of the New York and Massachusetts Chapters made to Springfield and Westfield, Mass., and New Haven, Conn., under the auspices of the Committee on Tests of the Society.

The Chapter is in a flourishing condition, having a total membership of 74, divided as follows: 2 honorary members, 65 members, 6 associates, and 1 junior.

The finances of the Chapter are also in good condition, with a balance in the treasury of $260.46.

We regret to announce the loss of a member in the death of Mr. N. P. Andrus, a charter member of the Society and the Chapter, who passed away January 13, 1913.

A committee was appointed to draw up fitting resolutions on

the death of Mr. Andrus to be sent to his family. A committee was also appointed to attend the funeral.

Respectfully submitted,

JOSEPH GRAHAM,
Secretary.

Chairman Hale: If there are no objections we will accept the report of the New York Chapter and place it on record. We will now hear the Massachusetts Chapter Report.

REPORT OF THE MASSACHUSETTS CHAPTER.

In October the Massachusetts Chapter had an outing to Wayland, and at this outing the speakers included Col. Everett C. Benton, Republican candidate for Governor of Massachusetts; Congressmen Samuel McCall and John W. Weeks; Councilor Alexander McGregor; District Attorney John J. Higgins and John J. Irwin, of the State Board of Agriculture.

The first annual meeting of the Massachusetts Chapter was held in Boston, November 19, and the following officers were elected:

President, Frank I. Cooper.
Vice-President, H. W. Whitten.
Secretary, J. W. H. Myrick.
Treasurer, William T. Smallman.

Board of Governors—J. A. Moore, D. S. Boyden, William G. Snow.

A meeting was held at the Boston Press Club, December 10, at which the members had as a topic for discussion, "Separation of Heating and Ventilating Contracts from the General or Other Contracts."

At this meeting Messrs. Cooper, McKenna, Franklin and Myrick were appointed a committee to draw up a bill similar to the New York State law for the separation of heating and ventilating contracts from the general contract, and to introduce such bill at the forthcoming session of the Massachusetts Legislature; also to confer with the other societies interested in such a measure.

This committee conference brought into our field the coöpera-

tion of the plumbers, steamfitters and electrical engineers. We are attempting to copy the New York law as near as it will apply to Massachusetts. We find a great deal of interest in our work among the architects. They have communicated with us and want us to appear before the legislature to try to carry a bill of that nature through. This is an interesting subject to us, though I dare say it is old to the members of the New York Chapter or the members of the Society here in New York, but such a bill will, I believe, be passed in Massachusetts and other States later on. From that sort of work I feel we are opening up a field of new interest for recruiting new members for the parent Society. Our meetings are generally held at some of the clubs in Boston, where dinner can be served at a reasonable figure, also where a private room for our meetings may be had.

Respectfully submitted,

J. W. H. MYRICK,
Secretary.

Chairman Hale: If there is no objection, the report of the Massachusetts Chapter will be accepted and placed on record.

The report of the chairman of the Committee on Compulsory Legislation has been sent in by Professor Hoffman, who is unable to be with us, in which case the Secretary will read it.

The report was discussed by Mr. Hale, Mr. S. R. Lewis, Prof. Kent, Mr. Weinshank and Mr. Haslett, and it was voted to postpone the discussion till Thursday morning at 10 o'clock.

Chairman Hale: The next on the program is the report of the Committee on Standards: first, the code for testing house-heating boilers.

Secretary Macon: The chairman of this subcommittee on standards, Mr. E. A. May, expected to be here, but now writes that it is impossible for him to attend. He says in view of the fact that there are some slight disagreements between the members of the committee on the code for testing boilers, which will have to be ironed out before the final report is made, he asks me to announce that this committee is well along in the work, but owing to the circumstances is unable to give us a complete report until the summer meeting.

Chairman Hale: You have heard the report. There are no remarks to be made in reference to it. We have nothing to dis-

cuss. The report of the Committee on Heating Guarantees is next in order. Mr. Mackay.

Mr. Mackay: Mr. Chairman, your committee have nothing further to report than that handed in at the last annual meeting. It has since been printed, so that the members can obtain a copy of it.

A motion to refer the report of the Committee on Heating Guarantees back to the committee for further report at the semiannual meeting was duly carried.

Chairman Hale: Report of the Committee on Tests, Mr. Soule.

Mr. Soule: Mr. Chairman, since the various members of this committee live in widely separated cities it became necessary for those members to work individually in collecting test data. Some members have been too busy to give time to this committee work. Several members have test data to report.

I have one subject to report on, namely, very accurate and thorough tests have been made during the present month on the efficiency of pipe coils under fan blast conditions at the Institute of Thermal Research in Buffalo. The results of these tests show that with equal frictional resistance to the passage of air through the blast heater, measured by equal power at the fan and with a given volume of air heated through a given range of temperature, the amount of heating surface required is the same whether it be one-inch pipe coils or cast iron radiators. A further report will be made on this matter at the semiannual meeting.

Chairman Hale: Mr. Donnelly, we would be glad to hear from you as a member of the Committee on Tests.

Mr. Donnelly: Mr. President and Gentlemen—The Committee on Tests in this section unfortunately consisted of only one man this year, instead of two men, as it did last year. Last year we were able to get together and run some tests, which were all observed by both of us and checked over by some other observers, who were there as members of the Society. This year I have started some tests, but, owing to the fact that there was only one observer of the Committee on Tests there, I do not think it is worth while to present them. I desire only to present such tests as have been observed by some other observer as well as myself.

Accompanied by Mr. Chapman, Mr. Lyle and others, in December last I made a visit to Yale by invitation of Professor

Breckenridge, of the Sheffield Scientific School. I suggested that I would like to bring some members of the American Society there to become familiar with what the Sheffield School was doing in heating and ventilating apparatus. He replied by extending a cordial invitation to all the members of the Society.

On the same trip we decided to visit the H. B. Smith laboratory at Westfield, Mass., about which I had written to the manager of the H. B. Smith Company some time previous. Also knowing that some tests were being made at the Y. M. C. A. building at Springfield, it was thought we could also see a test there while on the same trip.

We visited the Y. M. C. A. building at Springfield, and spent the evening of Wednesday, December 11, during which a test was made of the apparatus and a demonstration of its capabilities was shown to the visitors.

The next morning we took the trolley car over to the H. B. Smith plant. We went first through their radiator works and then through their testing laboratory, also through the plant where the boilers are manufactured, and we witnessed a test to very high pressure of some of their radiators picked at random from stock. We finally met as a body in their board meeting room, their engineer produced his books of data, and the manager, Mr. Reed, said that he would be glad to give any information he could, that we might have a general discussion on testing and allied subjects. We talked for an hour and a half or two hours, and brought out many points of interest. The engineering officials there informed us that we could send members of the Committee on Tests at any time, and, if we advised them when we were coming, they would put before us all the data they had collected on radiator and boiler tests, and from that data we might take as much as we saw fit and compile it into a report for the benefit of the Society. We returned to Springfield and had dinner again in the evening as the guests of the H. B. Smith Company.

The next morning we went down to the Yale Scientific School. Professor Breckenridge received us. He took us through the building, and showed us the equipment for heating the building itself, which is of considerable importance and of great interest. He showed us the laboratory and their method of testing boilers, radiators and fan blast apparatus, after which an invitation was

extended by Professor Breckenridge to us to come again, and to any other committees who could come. He also stated that anyone who had new and novel apparatus that they wanted tested, they could send or bring it to the school and the school would coöperate in making any tests that were required and largely without cost. That is, they would provide the coal and steam and light and attendance, and assist in the erection and do anything which would develop anything of value for the advancement of the science of heating and ventilation.

I think the great value of the trip was not in what was accomplished in itself, for it was of comparatively little use, but in bringing to the notice of the Society that there are places available where a great deal of data can be gathered by the Committee on Tests if they put themselves in communication with the right parties, and coöperate with them, we may gather data that may be depended upon as being impartial.

The semiannual meeting of last year in Detroit authorized the Committee on Tests to examine a series of tests of so-called radiator steam traps, that were made during the year in California by E. D. Griffiths, and a report of the same rendered to W. F. McClure, State Engineer. Several of these appliances were tested at this time. The manner of making this test was given to this Society by the courtesy of the State Engineering Department of the State of California, who sent a copy of the report and a blue print showing their apparatus, which your committee offers for the information of the Society. The Committee was also asked to make a report on the best method of testing radiator steam traps or vacuum return line systems. I have corresponded with the members of the committee, and written a number of letters to members of the Society on the subject.

Based on some of their recommendations and my own study of the subject, I submit the following report.

Reads report.

The report was accepted and referred to the incoming council.

After some discussion it was voted to recommend that each of the Committee of Five on Tests have power to add two local members to work with him, thus forming a local committee to make tests and collect data, the results of which are to be presented to the Society.

Chairman Hale: We will now hear from Professor Harding

in reference to the investigations he has made as a member of the Committee on Tests.

Prof. Harding gives his views on the friction loss referred to by Mr. Soule, and refers to his report as well as to a report on the transmission of heat through building materials. (See papers.)

Chairman Hale then called for the report of the Committee to the International Congress for Testing Materials. The report was read by Mr. Macon in the absence of the chairman of the committee, Prof. Hoffman.

Secretary Macon: In accordance with the request of the President, the undersigned attended the meetings of the Sixth International Congress on Testing Materials, held in the Engineering Societies Building, New York City, during the week commencing September 2, 1912, as the official representative of this Society, and hereby tenders the following report:

On Monday, the opening day of the Congress, the Engineering Societies Building was the scene of considerable activity. Dr. Henry M. Howe, President; Robert W. Lesley and Capt. R. W. Hunt, Vice-Presidents; Prof. Edgar Marburg, Treasurer, and H. F. G. Porter, Secretary, with a large corps of assistants, received the delegates and registered them. This was no small task and was well managed. The American delegation numbered about 500 and the foreign about 300. All told over 800 persons were registered, the most of them the first day.

Monday was devoted to registration and committee work. On Monday evening there was a formal reception under the auspices of the American Society for Testing Materials, the American Institute of Electrical Engineers, the American Society of Mechanical Engineers and the American Institute of Mining Engineers.

On Tuesday, the technical and scientific work of the Congress was formally opened at the morning session in the address of welcome by Capt. Hunt, President of the American Society for Testing Materials. Upon motion of Prof. Martens of Germany, Dr. Howe was elected President of the Association, to fill the unexpired term of the late Dr. C. B. Dudley. Dr. Howe then took charge of the meeting, after which addresses of welcome were made by General W. H. Bixby, representing the President of the United States; Governor John A. Dix, representing the State of New York, and Controller William A. Prendergast, represent-

ing the Mayor of New York. The first session closed with the President's address by Dr. Howe.

For the regular sessions the Congress was divided into three parts: Section A on Metals, Section B on Cements and Stone, and Section C on miscellaneous materials. These sessions were held Tuesday morning and afternoon, Wednesday morning, Thursday morning and afternoon, Friday morning and afternoon, and Saturday morning. Wednesday afternoon the Congress was taken by steamboat to West Point to visit the Naval Academy, returning about 10 P. M. Thursday night the American Society of Civil Engineers entertained the foreign members at a formal reception. Saturday afternoon and evening were given over to receptions by the officers of the American Museum of Natural History and by the officers of the Metropolitan Museum of Art.

Your representative is pleased to report that he was very faithful in his attendance upon the meetings but that, owing to the extreme cosmopolitan atmosphere and variety of tongues, he is not able to go into details as to the discussions, which at times were very animated. The discussions were rendered in three languages, English, German and French, and it was not unusual for the same speaker to render his speech in all the languages.

The value to the profession of such a gathering of scientific men can scarcely be estimated. The interchange of ideas is no doubt of great value in standardizing this work, but probably the greatest good will be found in the inspiration each receives from personal contact with others in the same profession.

Respectfully submitted,

J. D. Hoffman,
Chairman.

It was voted to accept the report and place the same in the transactions.

Chairman Hale called for the report of the committee appointed to confer with the National District Heating Association. Mr. Capron, the Chairman, reported the committee had not yet met the members from the National District Heating Association, but hoped to do so at an early date.

The committee was continued.

Mr. Weinshank presented a report of the Committee to the

National Conservation Congress. The report was accepted, but was voted to be left out of the minutes as not being pertinent to the work of this Society.

Chairman Hale: The Secretary has a report from the committee which was appointed to audit the books of the officers.

REPORT OF AUDITING COMMITTEE.

The undersigned have carefully audited the books of the Secretary and Treasurer for the year 1912-1913 and find them correct.

(Signed)

JAMES H. DAVIS,
FRANK K. CHEW,
W. T. TIMMIS.

Secretary Macon: Mr. Chairman, I move that the Society recommend to the Board of Governors the establishment of a fiscal year beginning the first of January and ending the thirty-first of December, every year. In connection with that motion I should think that it would follow that the dues would then be payable from January to January. It seems to have been an unwritten law—I don't know how it was established—but we have usually thought that the dues were not payable until about the end of this meeting, roughly, February 1, and that applied to the twelve months ending February 1, the following year. This motion would make it certain that the dues would be payable January 1, and each fiscal year of the Society would begin on January 1. Mr. Haslet seconded the motion, which was duly put and carried.

DISCUSSION RE MEMBERSHIP PROPOSALS.

On motion duly put and carried it was voted to inform the incoming Board of Governors that the grade of membership be left off the application blanks, and that when a candidate is accepted for an associate or junior membership the proposer shall be notified to ascertain if such grade is satisfactory to the candidate.

Chairman Hale: According to the Constitution and By-laws

voted upon last summer, the Nominating Committee for the nomination of officers of the Society for the following year are to be appointed at this time, and a ballot taken in this room to determine who that committee shall consist of. I will ask the Secretary and his assistant to pass the ballots around, but beforehand to invite suggestions as to the names of those whom we should vote for, for a committee to nominate officers for 1914.

Mr. Barron: Mr. President, will you kindly read the clause from the new Constitution covering that matter?

Chairman Hale: Yes. A Nominating Committee of five members of the Society, not officeholders, shall be elected by ballot at the annual meeting. It shall be the duty of this Nominating Committee to select candidates for the various offices that are to be filled at the next ensuing annual meeting. This committee shall present to the Secretary at least sixty days before the day of the annual meeting the names of candidates.

Mr. Haslett: Mr. Chairman, could that not very properly be postponed until some other session, until we get acquainted with each other and find out? Is it compulsory to take up the question now?

Chairman Hale: It is a part of the proceedings, and according to the program, and also according to the Constitution and By-laws. The members in a general way are pretty well acquainted with each other. I ask for nominations.

A ballot was taken and tellers were appointed to report the result to the chairman.

Chairman Hale: The committee to determine the vote for the election of the Nominating Committee for next year report as follows:

There were 35 votes cast. For Mr. Adams, 28; Mr. Davis, 26; Mr. Snow, 25; Mr. Munroe, 23; Mr. Soule, 19.

Chairman Hale: These five members are therefore declared elected. Is there any further business to be brought before the meeting? If not, a motion to adjourn is in order.

(On motion the meeting adjourned.)

First Day—Evening Session.

Tuesday, January 21, 1913.

(The meeting was called to order at 8:30 P. M. by Chairman Hale.)

Chairman Hale: The first order of business this evening is the report of the tellers of election. Mr. Davis will please report.

Mr. Davis: The undersigned committee, appointed as tellers to count the ballots for officers for the ensuing year, respectfully submit the following report:

There were 145 ballots cast, 4 of which were thrown out for various reasons, with the following result:

For President—
John F. Hale, 138;
S. R. Lewis, 2.

For Vice-President—
E. F. Capron, 124;
A. D. Franklin, 84;
N. L. Thompson, 59.

For Treasurer—
James A. Donnelly, 138;
U. G. Scollay, 1.

For Council—
Frank T. Chapman, 132;
Ralph Collamore, 129;
D. D. Kimball, 138;
W. W. Macon, 134;
J. M. Stannard, 130;
Theodore Weinshank, 92;
D. M. Quay, 51.

Respectfully submitted,

Frederick K. Davis,
Edward K. Munroe,
U. G. Scollay.

The Chair then announced: The President for next year will be John F. Hale; the Vice-Presidents, E. S. Capron and A. B.

Franklin; the Treasurer, James A. Donnelly; the Board of Managers, Frank T. Chapman, Ralph Collamore, D. D. Kimball, W. W. Macon, James M. Stannard and Theodore Weinshank. In addition to these, the two past Presidents, Mr. R. P. Bolton and Mr. John R. Allen, will become members of the Council, as our Board will be called hereafter.

Chairman Hale: We have been favored at this meeting with a paper by an engineer from the West, who has devised a peculiar and apparently meritorious method of ventilation in one of the schools in Rockford. Mr. Beery, the Chief Engineer of the Board of Education of Rockford, Illinois, has designed a system, and had it installed under his direction, and has written a paper descriptive of the apparatus. I will call upon Mr. Beery to read his paper on the subject of "Downward Ventilation in a Rockford, Ill., Schoolhouse."

Mr. Beery reads paper and also a supplemental paper added to the original.

The paper was discussed by Mr. English, Mr. Timmis, Mr. Macon, Mr. Davis, Mr. Willard, Mr. Turno, Mr. Barron, Mr. Snow, Mr. Teran and Mr. Franklin, after which Mr. Beery replied to the several questions raised. The thanks of the Society were then voted to Mr. Beery for his courtesy in preparing the paper.

Chairman Hale: The next paper is one by Frank Irving Cooper, of Boston, on the subject of air-conditioning and electric heating in a residence.

Mr. Cooper reads paper.

The remarks on the paper were by Mr. Franklin, Mr. Wolfe and Mr. Hale.

Chairman Hale: The next paper to be presented is "Efficiency of Air Washers in Recirculating Air," by Prof. George C. Whipple, of Harvard University.

Secretary Macon explained that Professor Whipple was unable to attend, but that Professor Affleck, who coöperated with Professor Whipple in these experiments, would address the meeting.

Professor Affleck: Mr. Chairman and Gentlemen—I came to learn, but if what we are doing at the Y. M. C. A. building interests you, it will afford us pleasure to explain or describe it. Professor Whipple, of the Harvard Sanitary Engineering Department, is coöperating, as in fact are several other gentlemen this

year, on a type of experiment which was not possible last year, and which would not be possible now without such coöperation as he and others are rendering. As some of you know, our experimentation last year was based almost exclusively on the regulation of humidity and temperature and the desirability of the specified temperatures and humidities, gauged entirely by the sensations of the men exercising in the room. We are continuing the same tests with recirculation of air this year, but in addition to that are making some rather more definite experiments. For instance, the physiological results on the men of different temperatures and humidities, including the body temperature, mouth and rectum; heart rate, blood pressure and response to certain endurance tests. Then we are further examining air and water, for instance, as to dust and bacteria. In recirculating, the air is drawn from the room, passed through the washer and returned to the room, and samples are taken just before the air enters the washer and immediately after it passes through the washer. Thus far the tests have been made by the exposure of gelatine and agar plates. It runs about thus on an average: about 90 per cent. of the bacteria colonies, as found in the exhaust air, are removed by the air washer; the figures are 130 to 12, and so on, about in that proportion. The moulds are about at a corresponding relationship. The dust test has not been conducted to any extent as yet, but we feel that there will be a removal of 50 per cent. of the dust particles. Our plan is to use the Wallace-Tiernan air sample for both dust and bacteria.

A determination of carbon dioxide is now being conducted in different parts of the room, both at different levels and at different points on the floor of the gymnasium; also of the air as it enters the washer and after it passes through the washer. The water in the vat is being analyzed as to carbon dioxide contained. In the analysis of the vat water we were rather surprised to find that there is practically simply a residual amount of CO_2, *i. e.*, three to four parts per million, in the vat of the air washer, after we have run for ten or twelve hours, then allowed the water to settle, and after operating and having the water agitated for an hour the water in the washer will not accumulate a greater quantity of carbon dioxide. We do not yet understand that.

We have also been promised the coöperation of Professor Winslow in the so-called antiphylactic test, made by Dr. Rosenau

and his associates at Harvard, to find out if this vat water contains in solution certain poisons found in the exhaled breath. We have microscopic analyses made of the water and the sediment, and we hope that as soon as Professor Winslow, of New York City, has disposed of some experiments which now occupy practically all of his time, he will use microscopic analysis to identify the sedimentary substances which are in this water. Thus far we know that a large portion of the sediment in the water is epithelial cells, a fact which we had very largely expected. There have been found so far no pathogenic bacteria whatever.

I do not know what Professor Whipple would have reported had he been here, but he reports in the water an odor characteristic of the gymnasium.

Our point of view, I may say, is the health of the men in the room. To improve that is what we are working for, and we more than welcome a visit or investigation and, most of all, the suggestions from members of this organization or others who are similarly interested.

Chairman Hale: I am sure we all appreciate the remarks made by the professor, and are glad to know of the work that they are doing, and we are hopeful that by and by we may have a paper from some one in connection with the work that will describe what they have accomplished, that we may make it a part of our records.

The next report to be presented to the meeting is that of the Committee on School Room Ventilation, together with the paper on "Experiments on Humidifying Air at the Oliver Wendell Holmes School," by Charles F. Eveleth.

In the absence of Mr. Eveleth, Mr. Cooper, Chairman of the Committee on School Room Ventilation, will read the report, as well as the paper by Mr. Eveleth.

Mr. Cooper: In submitting this report of Mr. Eveleth, I beg to state that it is an account of the experiments conducted in a school building, that your committee planned to have made, as is set forth in this committee's report of 1912, which plan was approved by the Committee on Heating and Ventilation, appointed to coöperate with your committee on these experiments, of the American School Hygiene Association; see Addenda D, in this committee report, Volume XVIII of the Society's Transactions for 1912, as well as in the report just read.

I also desire to state the doctors we came in contact with from the American School Hygiene Association showed a keen appreciation of what we were doing and proposed to do, and I feel sure we can count on their coöperation in any experiments we undertake for the advancement of the art.

The question is not altogether one of engineering. The best modern systems of ventilating do seem to do what is expected of them.

In the experiment reported by Mr. Eveleth, we were anxious to find what would be the effect on pupils in schools that were air-conditioned, in addition to being provided in other ways with heat and ventilating up to modern standards.

After much effort, Mr. Arthur Keller (who has since passed away) took up the matter with the Boston School Commission, and the matter was referred by them to Mr. Eveleth, who is a member of our committee, and very much interested in having experiments of this kind carried out.

An appropriation was made by the Boston school authorities, amounting to six or seven hundred dollars, for the purpose of arranging the apparatus and carrying out this experiment.

Mr. Whitten: The record of the boiler pressures through the week of February 5 to 11, as shown on the chart, indicates that the boilers were not carefully looked after, as frequently there was no pressure indicated on the chart at all, showing the building must have gotten quite cool between heating periods.

Chairman Hale: You have the report of the committee, which I think is more complete than any we have had in this connection before. Tests similar to this have been made in the West as well. You have probably heard of the tests made at the Normal School in Chicago. In that case, however, they experimented in one room only. This test being carried on in the entire building is much more conclusive.

After some further discussion it was unanimously voted that the thanks of the Society be tendered to Mr. Eveleth, and to the committee for their excellent report on air-conditioning and ventilation in schoolhouses.

On motion the meeting then adjourned.

Second Day—Morning Session.

Wednesday, January 22, 1913.

The meeting was called to order at 10:45 A. M. by Vice-President Hale.

Chairman Hale: The morning session is opened and the first paper to be presented is by Mr. Busey and Mr. Carrier. Mr. Busey will read it. It is unfortunate that the paper was not sent in in time for it to be printed and distributed to the members, but I hope you will give close attention to the reading and then be able to discuss it.

The same method of procedure will be followed as yesterday; that is, the discussions will follow one after the other, and Mr. Busey will reply to all questions at one time after the members have finished.

Mr. Busey reads the paper.

Mr. Chapman asked questions as to cost of space, loss of rental from space taken.

Mr. James Davis asked questions as to spacing of pipes.

Professor Harding asked about the basis for his factor regarding friction, etc.

Mr. Donnelly gave some reminiscences regarding the progress of fan construction and asked questions regarding cost of power.

Mr. McCann asked how the case would apply when all the exhaust steam was used from the engine for heating purposes.

Mr. Busey replied to Mr. Chapman that space in a factory need not be considered, as the ducts would be overhead, and in other cases the gain would compensate for the extra space taken.

To Mr. Davis: That he had tried different spacing of pipes and also vento heaters, and found the horse power to vary directly as the friction loss.

To Professor Harding: The question of how many diameters of pipe lost their velocity. I think 40 diameters is conservative, to say the least; probably 50 would be better. In the planing mill type, with a very smooth duct, probably 60, I don't know just what. I have made a great many experiments on this, and have more planned, which I hope to make use of some other time. But for ordinary work we generally take 40 diameters, or, if conditions are good, 50.

To Mr. Donnelly: I have shown in the curves the cost of power at the fan is a vital factor, and that the cost of power goes up much more rapidly than the cost of service comes down with increased velocities.

To Mr. McCann: It seems to me I have shown in these curves where in case we use a steam engine and the exhaust is used in the heating coils, the velocity may be higher. It is all a matter of how much your power is going to cost you. Where you use a steam engine and the exhaust is used in the coils the power is practically free.

Chairman Hale: There were five gentlemen asked questions. Do those replies answer the points that were brought out satisfactorily? If so we will thank Mr. Busey for his paper and go to the next subject.

Dr. Franklin is present. Dr. Franklin has been unable to present a paper in time to have it printed, but he will speak extemporaneously on the subject of ozone.

The doctor says that he will not speak in reference to the ozone machines, but they are here for you to inspect and to get what information you can from them after he has addressed the meeting.

Dr. Franklin then addressed the meeting.

A vote of thanks was tendered to Dr. Franklin for his entertaining and instructive address.

Chairman Hale: The next on the program is the report of the Committee on Standards for Motion Picture Show Places.

Report read by Mr. Frank T. Chapman.

The discussion on the report extended the session well into the afternoon, and it was voted to adjourn till Thursday morning, especially as a number of the members wanted to visit the Singer Tower with the ladies.

Third Day—Morning Session.

Thursday, January 23, 1913.

The meeting was called to order by Vice-President Hale at 10:55 A. M.

Chairman Hale: The first topic to-day will be "A Standard Method of Measuring Air Velocities at Registers." Mr. Haslett,

who has previously spoken on the subject, will open the discussion.

Mr. Haslett: Mr. President and Gentlemen—In Pennsylvania, New Jersey and New York, in connection almost exclusively with schoolhouse work, we have a law that requires 30 cubic feet of fresh air per pupil per minute; and as time goes on they have been amending the law so that inspectors have been employed by the different States whose business it is to measure the air in the room at the warm air register to find out whether the law is being complied with or not; and each State has from two to ten inspectors, and each inspector has his own peculiar practice or his own peculiar ideas and views as to how this measurement should be made. One inspector will claim that the anemometer should be held at the four corners of the register and then in the center, and in that way arrive at it. Others contend, four other points should be selected on the face of the register and the air measured in that way. Other inspectors claim that a thick wall coming up will interfere with the flow of the air, hence they place the anemometer at the bottom of the warm air register and gradually raise it until it moves, and deduct from the face of the register of the amount of that area. There are so many different ideas that it occurred to me that this society should very properly go on record as standardizing a system of measuring air at the warm air register; because we are all subject to the law. It was for that reason I asked permission to introduce this matter at this time. I would like to hear the expression of the members of this Society or a committee appointed to consider the question and report with a recommendation for a standard. I have no idea of how it should be disposed of or the best way to dispose of it, but with these brief remarks I think you can see the very great importance of this Society going on record in this connection. We can then refer to a rule of the American Society of Heating and Ventilating Engineers, just as the general public now point to rules that have been laid down by the American Institute of Architects, which relieves the client and the architects and contractors and everybody else. I would like to have that question discussed.

A long discussion on the subject obtained, and was participated in by Mr. Chapman, Mr. Lewis, Professor Kent, Mr. Williams, Mr. Busey, Mr. Lyle, Mr. Whitten, Mr. Macon and Mr. Baldwin.

It was finally voted to ask the Chairman to appoint a committee to confer with the members and to report later in the day on a standard method of measuring the velocity of air through warm air registers when using the anemometer.

Mr. C. A. Haslett, Mr. A. Edson Hall and Mr. J. I. Lyle were appointed a committee to report at the afternoon session.

Chairman Hale: The next subject for us to consider is a paper entitled "Analysis of a Combination Heating System for a Residence," by Mr. Frank K. Chew.

Mr. Chew reads paper.

Chairman Hale announced the time for discussion on this paper would have to be curtailed to enable them to complete the work allotted for the session.

The paper was discussed by Mr. Lewis, Mr. Williams, Mr. Davis, Mr. Baldwin, Mr. Hale, Mr. Donnelly and Mr. Macon, after which several questions that were raised were replied to by Mr. Chew.

Chairman Hale: The next paper on the program is one by Mr. Norman A. Hill, "Efficiency of Labor Element in the Heating Industry."

Mr. Hill is unable to be present on account of illness, but sent us a letter, in which he encloses his unfinished paper for the Society to discuss if they saw fit.

It was voted to thank Mr. Hill for his effort and to ask him to complete the paper and submit it to us at a later date.

Chairman Hale announced at this period that Mr. F. K. Davis has arranged for a trip to-morrow morning, to see certain parts of the Grand Central Station, now in the process of construction. Those desiring to go are requested to meet at 10 A. M. at No. 70 East 45th Street.

Chairman Hale: Mr. Vrooman desires to present a resolution and I now offer him the opportunity.

Mr. Vrooman: "*Resolved*, That certain days or sessions of the annual meeting of this Society shall be devoted to a special definite subject relating to heating or ventilation: that the subject shall be decided at one annual meeting for the next; that one object of the papers and discussions of this meeting shall be to establish, approve, adopt and publish rule or rules, formula or formulas, as shall be designated by the Society."

Professor Kent proposed that the resolution be presented to

the Council for their consideration, stating that it was not the object of this Society to fix standards or formulas, but that its custom and also the custom of similar societies was to appoint committees to report on all such matters and then to accept such a report as the opinion of such committee.

After further discussion by Mr. Donnelly, Mr. Macon, Mr. Hale and Mr. Whitten, it was voted as the sense of the meeting that this matter should be referred to the Council, but it was also voted, on motion of Professor Kent, that the Society express itself in its transactions by receiving or accepting the reports of its committees on any technical subject for which such committees are appointed.

The meeting adjourned at 1:10 P. M.

Third Day—Afternoon Session.

Thursday, January 23, 1913.

Meeting was called to order at 2:45 P. M. by Vice-President Hale.

At the request of Chairman Hale, Mr. Samuel R. Lewis, of Chicago, one of the members of the Council, took the chair for the purpose of installing the newly-elected officers.

Mr. Lewis expressed his appreciation of the honor of his being asked to assume the chair.

Chairman Lewis then requested Past President Mackay to escort newly-elected President Hale to the platform.

Mr. Lewis explained the fact that, owing to the short time remaining in the session, he would ask that the other officers elected be escorted to the platform, after which they were duly installed by Chairman Lewis, after which President Hale took the Chair.

President Hale then requested Secretary Macon to continue in his office until the newly-elected Board of Managers should meet and appoint a Secretary.

President Hale: I will now call for the report of the committee appointed this morning to determine the best way to take anemometer readings at registers.

Mr. Haslett presented and read the report, after which it was

discussed by Professor Kent, Mr. Whitten, Mr. Lyle, Mr. Macon, Mr. Lewis, Mr. Baldwin and Mr. Williams.

After the discussion it was voted to accept the report and enter the same in our proceedings.

President Hale at this time asked for a further report from the Committee on Compulsory Legislation and, after considerable discussion, a motion was made that the report be returned to the committee with the request that they consider the points raised in the discussion and make a later report embodying the features mentioned by the members, and further investigation among themselves, based upon the thoughts expressed at this meeting.

The motion was put to vote and carried.

President Hale: The Secretary announces that he has a letter here from the American Society of Mechanical Engineers, in regard to the enlarged sizes of the extra heavy companion flanges.

Mr. Gombers: Just as a matter of information I can tell you what is being done in conjunction with the present committee of the Association of Master Steamfitters, coöperating with a joint committee from the American Water Works Association and the New England Water Works Association, as well as one of the departments of the government; and I can inform you also that the proposed schedule will be submitted to the body of manufacturers on a similar basis as that upon which the former schedules were submitted to the Association of Manufacturers. The work of standardizing flanges is taken up at the request of the United States Government and others that the schedule of the sizes of standard flanges be carried out from 30 to 100 inches inclusively, and all extra from 26 to 48 inches inclusively. And, for the first time, within my knowledge at least, the Water Works Association is now coöperating. They themselves had their specifications at a meeting with the New England Water Works Association, held in December last in this city, which was the means of bringing those two societies together on a common basis. I am glad this matter has come up before this Society, because the report of your committee, Professor Kent as Chairman, accepted the recommended schedule.

On motion, duly put and carried, the President was requested to appoint a committee to coöperate with the committee of the Mechanical Engineers, in connection with the extension of the standards to larger size flanges.

President Hale: The committee will be appointed in due time. I will not take the time now.

There are a number of topics for discussion on the program. Is it your wish that we should continue with them? It is almost five o'clock. We have a Council meeting for organization of the new Council immediately after this meeting, and the new Council will have some work to do. Is it your wish that we should continue and listen to these topics of discussion, or will some one make a motion that we adjourn?

Mr. Donnelly: There are one or two questions we should settle. I think the question of where we should hold the summer meeting should be given a few minutes' discussion, and then there is one question, started, I think, at the Detroit meeting, that there might be a possibility of a more desirable location for occasionally holding the annual meeting than in New York City. The Society now has a Chapter in Boston, and I think there are a number of members in the West who may prefer once in a few years to go to Boston for the annual meeting. It is possible that an annual meeting held in Philadelphia would result in a Chapter being organized there, if one is not organized before that time. Mr. Williams has spoken of the possibility of a Chapter in Pittsburgh. Perhaps we could hold a summer meeting rather than a winter meeting in Pittsburgh. There has come, I believe, an invitation to hold the summer meeting in Richmond, Virginia. That is rather far south for a summer meeting. Under the constitution we must hold our winter meeting in New York City. Perhaps Washington, under the new Democratic administration, with its improved conditions, the Senate and House being in assembly in January, might be a good place for the Society to go for its winter meeting. The Council, I believe, contemplate some changes in the articles of incorporation, and perhaps in the Constitution, hence it is perfectly feasible, I believe, to leave the requirement out of the Constitution that the annual meeting must be held in New York City. Speaking individually, as a New York member, I do not think we should be selfish and always hold this meeting in New York City. If the out-of-town members would like to have it distributed up and down the Atlantic Coast occasionally, there is no reason why we should not do so.

Professor Kent: As I said to Mr. Donnelly to-day, our Con-

stitution confronts us. I understand that the Mining Engineers, under their constitution—I think it is amended now—had a similar restriction. They got around it by having the annual meeting in New York City, and they sent a circular that no one was expected to attend that except the officers, that there would be a professional meeting at such another city on such a date; and the annual meeting would be adjourned there. So we could have an annual meeting here one afternoon and then adjourn to Richmond, Virginia, the following week without changing the Constitution. I surmise Mr. Donnelly has something up his sleeve about amending the Constitution, which can be referred to the Council to be taken care of.

Mr. Quay: The Council might prefer to have the opinion of the organization as to the advisability of this plan, and probably a motion would be in order that it is the sense of the meeting that there will be no objection to the Council carrying out such a plan if they find it feasible. I make that as a motion.

President Hale: That it is the sense of this meeting that certain things be recommended to the incoming Council? Kindly repeat that.

Mr. Quay: No; the sense of the meeting that the Society has no objection to the Council deciding to have the annual meeting in another city on the plan suggested by Professor Kent, if they find it advisable.

(The motion was put to a vote and carried.)

President Hale: Is there any further business which any members wish to bring up?

Mr. Donnelly: I would like to make a motion that these topics for discussion which have been printed should be distributed to the members for use at the summer meeting when these topics shall be up for discussion.

Mr. F. K. Davis: If Mr. Donnelly would accept an amendment to his motion I would like to suggest that those topics be sent to the membership for a written discussion before the summer meeting. This was accepted by Mr. Donnelly and the motion was carried.

(On motion the meeting adjourned.)

LIST OF MEMBERS AND GUESTS PRESENT AT THE NINETEENTH ANNUAL MEETING, JANUARY, 1913.

New York, January 23, 1913.

MEMBERS.

Addams, Homer
Armagnac, A. S.
Armstrong, C. G.

Bacon, John H.
Bailey, H. F.
Barron, H. J.
Barwick, Thos.
Beery, C. E.
Blackmore, J. J.
Bolton, R. P.
Boyden, D. S.
Bradley, J. T.
Brooks, H. H.
Busey, F. L.

Capron, E. F.
Carney, J. F.
Chapman, F. T.
Chase, C. F.
Chew, F. K.
Clark, W. D.
Collamore, Ralph
Cooper, F. I.
Cripps, A. G.
Cryer, T. B.
Culbert, W. F.

Davis, F. K.
Davis, J. H.
Dickinson, W. S.
Doherty, P. C.
Donnelly, J. A.
Dornheim, G. A.
Downes, W. H.
Driscoll, W. H.

Edgar, A. C.
Ellis, H. W.
England, G. B.

Fabricius, Paul H.
Farnham, Geo. D.
Faulkner, J. C.
Fielding, H. H.
Flagg, C. N., Jr.
Fox, E. E.
Franklin, A. B.
Franklin, M. W.
Fuller, C. W.

Gombers, H. B.
Goodnow, W. F.
Graham, Jos.
Greey, G. V.

Haensel, C. W.
Hale, John F.
Hall, A. E.
Hanbury, J. F.
Hankin, Richard
Hanlon, John S.
Harding, L. A.
Haslett, C. A.
Heath, F. R.
Hinkle, E. C.
Hunt, Richard B.

Issertell, H. G.

Kent, Wm.
Kieb, A. A.
Kimball, D. D.
Kiewitz, A. A.
Kiewitz, Conway

Lemmey, Robert
Lewis, S. R.
Lyle, J. I.

Mackay, W. M.
Mackinnon, R. B.
Macon, W. W.
Maginn, P. F.
Mallory, H. C.
Mappett, A. S.
Marshall, W. J.
McCann, F. G.
McDonald, W. F.
McGinness, J. E.
McKenna, W. N.
Merritt, J. H.
Miller, C. A.
Miller, M. P.
Moore, F. S.
Morrison, Chas.
Munroe, E. K.
Myrick, J. W. H.
Nelson, Benj.
Newkumet, P. H.

O'Hanlon, Geo.

Phegley, Frank
Purdy, F. G.

Quay, D. M.

Robertson, G. A.
Ritchie, Wm.
Ritter, Arthur

Schroeder, M.
Scott, C. E.
Scott, E. A.
Scollay, U. G.
Schmidt, G. G.
Seward, P. H.
Sherman, L. B.
Slocum, C. A.
Snow, W. G.
Soule, S. C.
Sprague, Douglas
Stannard, J. M.
Staten, C. H.
Stevens, F. H.
Stockwell, W. R.

Taggart, R. C.
Teran, C.
Thomas, W. S.
Timmis, W. S.
Treat, E. J.
Turno, W. G. W.

Vrooman, W.

Warsop, C. E.
Webster, Warren
Weinshank, Theo.
Welsh, H. S.
Whitten, H. W.
Williams, H. D.
Willis, Oliver E.
Wilson, F. A.
Wilson, Thos.
Wolfe, G. C.
Wolfe, W. F.

GUESTS.

Affleck, G. B.
Applegate, E. F.
Ashland, Chas.

Baldwin, W. J.
Beatty, H. C.
Bergen, G. L.
Bilyen, W. F.
Braemer, Wm. G. R.
Bristol, W. D.
Brown, T.
Butler, E. H.
Bulkeley, Claude A.

Campbell, C. G.
Campbell, H. A.
Clarke, C. B.
Conklin, G. W.
Cunningham, C. E.

Darling, Edward
Darts, J. A.
Devitt, W. J.
Driggs, L. L.

Eagan, G. A.
Engle, Alfred
Engle, H. J.
Ennis, W. N.
Ewald, Rudolph

Fischer, F. R. W.
Fitts, J. L.
Frean, C. W.

Garfield, J. B.
Gross, A.
Gurnee, S. W.
Guthorn, S. D.

Hunter, W. D.
Hutton, Wm.

Irwin, Battle

Keeney, F. P.
Kessler, Raines
Krauss, E.

Lambert, Wm.
Lanning, E. K.
LeCompte, W. G.
Lincoln, C. C.

Makin, J. S.
Martin, J. F.
McDowell, J. H.
Morford, T. E.
Moses, P. R.
Munroe, W. R.
Myers, D. M.

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PAPERS

OF THE

NINETEENTH ANNUAL MEETING,

New York, January 21, 22, 23, 1913.

CCCIV.

DEVELOPMENTS AND PRESENT PROBLEMS IN HEATING AND VENTILATION.

BY JOHN R. ALLEN.

Address by the President.

No branch of engineering science is more concerned with human health and comfort than heating and ventilation. Twenty years ago heating was largely a mechanic's art, and the design of the heating plant was left to the plumber and the steamfitter. Gradually a demand arose for more elaborate systems of heating, the problem grew too complicated for the artisan, and the design of heating systems became a special branch of mechanical engineering. With the growth of our cities, and the accompanying increase in density of population, there was added to the problem of heating that of ventilation, a very vital one considered from the standpoint of human health. In the early history of heating and ventilation the engineer was primarily concerned with designing a plant which could be satisfactorily operated. To-day this difficulty has been overcome, and the field for development now lies in improving the construction of the plant, so as to attain greater economy in operation and more comfort and health for the users. At the same time in striving for these conditions the artistic treatment of the plant must not be lost sight of. The United States has done as much or more in the application and development of heating and ventilating science than any other country of the world, but there is still much left to do, even in the elementary development of this science.

The first need in the science of heating was exact data from which laws could be developed. The steamfitter developed certain "rules of thumb", based upon experience, excellent as far as they went, but not fundamental enough to permit of extensive application. When the engineer took up the problem his first

efforts were directed to obtaining exact data, the easiest data to obtain and the most necessary being the heat losses from the various forms of radiation. These losses have now been obtained by different experimenters for all ordinary forms of radiation, both direct and indirect. It is possible with the data available to determine, within a small percentage of error, the exact amount of heat which will be given off by the various forms of radiators under different conditions and the laws governing the loss of heat from radiation under ordinary conditions are well understood.

With the introduction of the fan system new problems were added which rendered necessary the obtaining of more data, and the development of additional laws. Various experimenters have developed laws for the heat loss from fan radiation and, while no particular law is accepted at the present time, nevertheless the results which may be expected from fan radiation can be predicted within a reasonable degree of accuracy. There is yet work to be done in this field, but we may soon expect to have laws developed which will be generally accepted by engineers. Much of this useful data has been obtained by the manufacturers, who deserve every credit for the valuable and accurate information which they are now able to give to their clients. The American manufacturer has been quick to see the advantage of giving this information to the engineering profession and has been of great assistance to the engineer in intelligently designing a plant so as to use properly the apparatus furnished by the manufacturer. While twenty years ago very few manufacturers actually knew what their apparatus would do, the progressive manufacturing concerns of to-day maintain complete and well-equipped experimental laboratories, and are prepared to give scientifically accurate data in regard to the apparatus which they produce. In probably no other country in the world have manufacturers been so liberal in publishing data in regard to their apparatus, and the wisdom of this policy commends itself to every liberal-minded engineer. But what about the more fundamental propositions, in which the manufacturer is not concerned, and which the scientist has not yet investigated?

In the problem of designing a heating system there are fundamental problems which do not concern the manufacturer and

which require elaborate and costly apparatus in order to obtain accurate results. This is particularly true when we endeavor to determine the heat transmission and loss from the various forms of building constructions and the effect of the heat absorbed and given off by the building structure. The most accurate information in regard to the heat loss through building material is that obtained by German experimenters, the results of which have been translated into English by a member of our own Society. These experiments, however, were made with building constructions quite distinct from our own, and under different climatic conditions. I do not know of any extensive experiments having been made in this country to determine the heat losses in various forms of building constructions used here. Such data are particularly desirable for the newer forms of building constructions, such as hollow tile, hollow cement bricks, reinforced concrete and vitrified brick. Our modern office buildings present many new problems in heat losses which have not been investigated, and the reason why these investigations have not been made has not been from lack of interest or of desire on the part of the experimenter to obtain these data, but from the difficulty and expense involved in making the necessary experiments. Such experiments, which can be completely carried out only by the Government, or by a bequest from some fund provided for the purpose, are of the greatest importance to the whole community, as they concern the well-being of each individual.

Another consideration which has not been scientifically studied is the question of the proper temperature at which the air in a room should be maintained. In the United States it is customary to assume that a temperature from 68 to 70 deg. Fahr. is most suitable for rooms in which persons are not actively engaged. In Germany for similar rooms a temperature from 65 to 68 deg. Fahr. would be regarded as sufficient, while in England a room is considered properly heated when the temperature is 55 to 60 deg. Fahr. In one of the great English universities, classes are often held in rooms where the temperature does not exceed 55 deg. Fahr., but, under the same conditions in the United States, the class would be at once dismissed. What is the reason for this difference of temperature required by different nationalities? Is it due to personal peculiarity, custom, or climatic conditions? Possibly the proper temperature in one

locality may be different from that of another. The outside temperature may have much to do with the temperature required indoors, as it is a well-known fact that people living in countries where the temperature is extremely low usually require higher indoor temperature. Certainly these points are worthy of scientific investigation, as our only guide at the present time is custom, and what few data we have are fragmentary and not at all conclusive.

Many rules have been proposed for determining the proper amount of radiation to be placed in a room, and practically all of these rules are based on the assumption that the heat so applied to a room shall equal the heat lost from the walls and the windows. There are other conditions entering into the determination of the proper amount of radiation that should be placed in a room which are often allowed for by adding on percentages, but the percentages allowed in most cases are not based on any scientific hypothesis. For example, the intermittent heating of a room will affect the amount of heating surface to be placed in the room and the amount added will depend upon how quickly it is desired to heat the room after it has been cooled.

Where buildings are intermittently heated or are of heavy construction, far more heat is required to warm the walls of the building in a reasonable length of time than to take care of the heat transmission. Again, most of the rules used in determining the amount of radiation to heat a given sized room assume that the room must be heated at a temperature corresponding to the lowest temperature which exists outdoors for any length of time. Theoretically such a proposition is absurd, as obviously if just enough heat was supplied to provide for the heat loss from the room and the conditions all remained constant, it would require an infinite length of time to warm the room. Fortunately the heating engineer figures the radiation to heat the building at a much lower temperature than the average; and during the warm days heat is stored in the walls from the excess given off by the heating plant and absorbed from the sun. During the very cold days this heat is given up and reduces the heat loss from the building, serving to correct the errors in the engineer's calculations. In many of the great cathedrals of Europe no heating system is provided, and these buildings are never uncomfortable, owing to the heat stored in

the building structure during the summer months, and returned to the air during the colder months. A good example of the use of the heat stored in a building comes from Germany.

Recently a state dinner was to be given in a castle which had no heating system. The engineers were asked to heat the building for the dinner, but it was specified that no portion of the heating system was to be visible in the room. The result was accomplished by means of stored heat. For a number of days previous to the dinner, the floor of the dining-room was covered with steam pipes and these pipes were kept hot by means of a temporary boiler. The day before the dinner all the pipes were removed and the stored heat in the walls maintained the room in a perfectly comfortable condition for a number of days, although the outside temperature was well below the freezing point. None of our rules for heating take these conditions into consideration. It is quite possible that it would be better in buildings of heavy construction to base the necessary amount of heat to be supplied not upon the minimum external temperature, but rather upon the average external temperature for a period of time. Most heating engineers allow a large margin of safety to cover their ignorance of the conditions entering into the problem.

There is still much need for the development of a more comprehensive method of determining the amount of radiation necessary to heat a given building. The formulæ at present used do not include many factors which enter into the problem, and, in order to check existing rules, it will be necessary to have available the data obtained from actual installations in daily operation. The lack of information in regard to the actual operation in heating plants is very noticeable. A heating engineer may design many plants and, if there are no complaints, he assumes that the plants are working properly; but very few of us have investigated our own heating installations so as to find out whether the results obtained were in accordance with the computations originally made. Here, again, the obtaining of data and working up such a test involves much labor and expense, and such a test to be of any value must be carried on over a long period of time, while conditions and results are closely observed. In the proceedings of this Society there are descriptions of heating plants which have been installed, but there are very few

data in regard to the actual operation of such plants. It would be very interesting to know the heat loss per square foot of external surface for different conditions of outside temperature and wind, the heat loss from radiation for a long period of time, the effect of heat storage in the building walls during rapid changes of temperature, and many other details which might be obtained from such a test properly carried out. The compilation of such tests would be of great assistance in formulating some more logical rules for estimating heating surfaces.

Ventilation has been a natural outgrowth from the development of heating; as buildings have been made more and more impervious to the passage of air in order to prevent loss of heat, there has arisen the need of supplying fresh air. Even less is known scientifically about ventilation than is known about heating. The engineer assumes in the beginning of the computation that certain changes of air are necessary, depending upon the use for which the room is intended and the number of persons in the room. What fundamental scientific reasons are there for the changes of air ordinarily assumed? Dr. Leonard Hill, in the address before the Physiological Section of the Royal Society of Arts, describes a series of experiments which go to show that chemical purity of the air is of very little importance. In the worst ventilated rooms the percentage of CO_2 does not exceed by more than one or two per cent. the normal CO_2 of the air, yet at each breath we rebreathe much of the air just given out, and only about one-third of the air is expelled from the lungs at any one time. No man breathes pure air into his lungs, even when out of doors, and a change of one or two per cent. in the CO_2 of the air breathed would make no appreciable difference in the amount of CO_2 and other impurities in the lungs. The air of a room is usually assumed to be unfit for breathing when it has a bad odor, but an offensive odor does not necessarily make the air bad. Dr. Hill performed the following experiment:

A small experimental chamber, built of wood and fitted with a glass window for the purpose of observation, was made absolutely air tight. On one side of the chamber were placed two small electric heaters and a tin vessel of water, by which the air could be saturated with water vapor. On the other side was placed a large radiator, through which cold water could be cir-

culated so as to cool the air. The room was also provided with electric fans, so that the air in the chamber could be thoroughly agitated. In making the experiments seven or eight students were confined in this small room for about one-half hour at a time. During the experiments the CO_2 reached 4 per cent. above the normal, and the oxygen fell to 16 per cent.; the wet bulb thermometer rose to 85°, and the dry bulb to 87°. Under these conditions the students began to lose their spirits and their faces became flushed, but when the fans were started and the air in the room agitated, their discomfort ceased. The improvement in their feelings was doubtless due to the cooling of the skin, consequent upon the change of air in the clothing near the skin. Persons outside the box breathed the chamber air by means of a tube, and felt no discomfort; on the other hand, if the persons inside breathed air from the outside they gained very little relief, although by cooling the air in the box the discomfort was relieved very much. The author concludes that the discomfort experienced in crowded rooms is not due to the increase in impurities, but to the conditions in temperature, the lack of movement in the air, and the diminished heat lost from the body. These experiments show that our knowledge of the effects of ventilation is really very limited, and that, after all, the CO_2 test for the condition of air in a room may be of little actual value.

There is a great field for experimental work along these lines, but to carry out such experiments they must be done jointly by the heating and ventilating engineer and the physiologist. There are many things that we should know, such as: What constitutes pure air? What are the safe limits of purity? How may these be determined? At what temperature should air be used for ventilation? What effect does the rapid circulating of the air have on ventilation?—and many others. These questions are largely physiological, but, at the same time, it will be necessary, in carrying out such experiments, to have the engineer produce the conditions of the experiment and the physiologist to record the results. It is even possible that our Society might invite a joint consideration of such topics with similar societies interested in Physiology.

The heating and ventilating system may have much to do with the spread of disease by bringing germs from the outside

air into the room; indeed, what better means for carrying germs can be provided than the central ventilating system for distributing the germs from the fan room throughout the whole building? A paper read before our own Society shows that the higher the temperature of the air used in ventilation, and the higher the temperature of the radiating surface, the greater the amount of dust carried with the air; and with this dust are carried the germs of disease. This fact alone may account for the complaint that is sometimes made by hospital surgeons that patients in rooms ventilated by air which has passed over steam coils do not improve as rapidly as patients in rooms ventilated with unheated air. This is another fundamental question in ventilation which is very important and needs a thorough investigation to enable the heating engineer to design a plant which will best suit the needs of the persons in the building to be ventilated.

In the design of the heating plant for buildings of an artistic character, the heating and ventilating engineer should make his installation conform to the artistic treatment of the building. So often we see an artistic room, with artistic hangings, heated with a radiator, the design of which is the one discordant note in the room. Manufacturers of radiators and heating equipment are just beginning to realize this, and are designing simpler and more artistic patterns, for, after all, there is no reason why the design of the radiator should not be as much a part of the interior design of the room as the design of the hardware and the electric lighting fittings. The designers of hardware have produced fittings appropriate for all the principal styles of architecture, and these have been designed not by engineers, but by artists. There is still room for improvement in our radiator designs, so that they, too, may conform to the various styles of building architecture. The ancient Greeks and Romans in their buildings often entirely concealed the heating system by circulating the hot water or vapor underneath the floors or behind marble slabs.

This address has endeavored to point out to the members of our Society some of the fundamental facts that are usually assumed as settled; but about which, in reality, we know very little, and in regard to which we need much additional information. In regard to the obtaining of more experimental facts

upon which to base our calculations the following suggestions are made:

There are many universities and private laboratories that are investigating these problems, but this work of investigation is more or less incomplete, and the investigations are not co-related so as to obtain the best possible results. Much time could be saved if each of these installations could take up the lines of experiment which they are best able to carry out and make these experiments in accordance with some prearranged plan. This Society could then serve as a means through which the lines of experiment might be suggested to the laboratories, and they could also serve to collect the data obtained and have them classified and compiled. There would, no doubt, be many difficulties in bringing about such a combination of laboratories, but a closer relation between this Society and the various laboratories would result in much profit to all interested in these problems. If such a closer affiliation be made, it is possible that, in course of time, the combination of laboratories suggested might be brought about.

This Society should be intimately associated with the members of the medical profession and physiologists who are investigating the problems of sanitation and the public health. The members of our own Society should endeavor to be familiar with the most recent experiments along these lines. As has been suggested, the joint experiments, conducted by the trained physiological investigator and the engineer, could do much to clear up the present uncertainties, particularly in ventilation. Any arrangement by which an interchange of ideas between the physiologist and the engineer may be brought about would be a first step to obtaining more exact information along these lines.

We have other problems, however, which require very elaborate apparatus and ample means to investigate thoroughly. Such investigations are too extensive to be taken up by the laboratories of our manufacturers and universities. Such problems as the heat losses from buildings, the effect of heat stored in the building structure, and similar problems must be investigated by men competent to conduct such experiments and who must have ample time, plenty of assistance, and adequate financial means. Such experiments are beyond the financial resources of universities, and are not vital enough to the interests of our manufac-

turers to warrant the expense involved in conducting them. The funds necessary to carry on such experiments should be provided by the government or by the trustees of large bequests which have been given for the purpose of investigating subjects which would be of benefit to the whole community. The subjects I have mentioned are directly concerned with the health and comfort of every community in the United States, where heating is required. It would be perfectly proper for our Society to endeavor to interest persons or institutions of large means in establishing an experimental laboratory in which matters pertaining to heating and ventilation and allied subjects could be investigated.

In our Society let us take a broad view of the field of heating and ventilation, and, if possible, endeavor to solve the fundamental problems and develop the basic laws upon which our calculations may be founded, having in mind each year to take one more step in advancing heating and ventilation from a mechanic's art to a science.

CCCV.

DOWNWARD VENTILATION IN A ROCKFORD, ILL., SCHOOLHOUSE.

BY CLINTON E. BEERY.

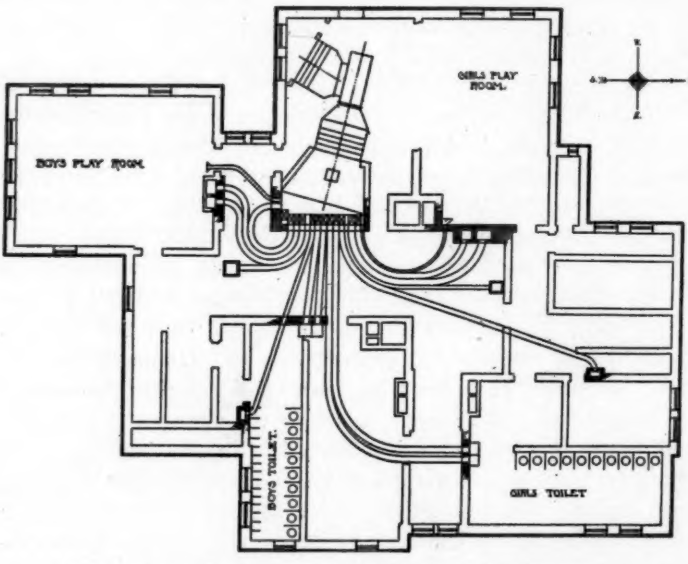
The system of heating and ventilation for the Hall School Building, Rockford, Ill., was designed by and installed under the supervision of the author last summer, and has been in operation since the beginning of the last school year. In view of the generally accepted theories of heating and of the revolutionary tendencies in the method designed by the author, together with what appears on first thought to be a freaky arrangement, he desires to make a brief explanation, believing it will help to convey a clearer understanding of the theory on which this method, which will be referred to hereinafter as the new method, operates. Incidentally, a patent has been applied for on the system.

In the author's experience, based for the most part on practice and observation, I became impressed with the importance of saving, if possible, the great heat losses frequently found in fan-blast heating and ventilation, which seemed to me not only a waste, but actually a handicap to best results. With the knowledge that air of lower temperature and greater density always finds a position at the floor, and that higher temperatures prevail at the ceiling, he reasoned that, if the temperature near the ceiling could be controlled by some means other than the ventilating apparatus, the air customarily at a high temperature at or near the ceiling could be held to a minimum difference in temperature between the floor and the ceiling, and in this way a beneficial influence could be produced on the results obtained from the ventilating apparatus.

With this as a basis for my theory I arranged, on January 3, 1912, a regular school room, referred to hereafter as room No. 3, for experimental work to demonstrate my theory. Several other rooms in the building were operating as in general prac-

tice. This was the first season for the heating and ventilating system, and it was giving good results.

Room No. 3, which is in the northwest corner of the first floor, is the coldest room in the building. Room No. 8 is on the second floor, directly over room No. 3, and is an exact duplicate of it. Each of these rooms is 26 ft. by 31 ft., with ceilings 13 ft. 6 in. high. Each has 100 sq. ft. of glass exposure facing the west, and 50 sq. ft. of glass exposure facing the north. All

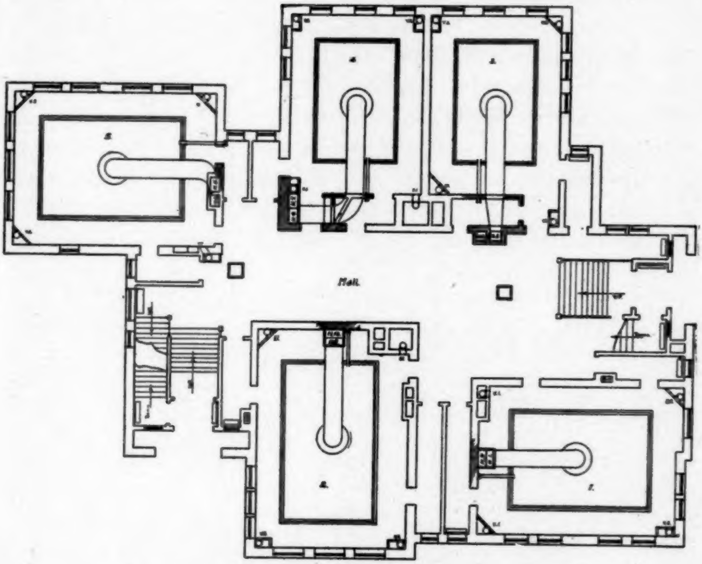


PLAN OF THE BASEMENT OF THE ROCKFORD SCHOOLHOUSE.

windows are protected with wooden grooved weather strips. These two rooms were operated the remainder of the heating season, and more or less careful observations of their operation noted.

During the early part of January a comparative test was made of the temperature in room No. 3 (the new method) and room No. 8 (the regulation method), with 60 sq. ft. of wall radiation in the northwest corner. The air delivery in the rooms was 1,544 to 1,560 cu. ft. per minute, measured at the exits. Twelve temperature readings were taken at 5-min. intervals in each corner of both rooms. Twelve readings of the temperature of the en-

tering air were also taken at 5-min. intervals. The outside temperature at the time of the first reading was 2 deg. below zero F., and at the time of the last reading 3 deg. below zero F. An



FIRST FLOOR PLAN OF THE ROCKFORD SCHOOLHOUSE.

extremely cold west wind, estimated at 18 to 20 miles per hour, was blowing. The maximum and minimum temperature, Fahrenheit, of the twelve readings taken are given in the accompanying Table I:

TABLE I—MAXIMUM AND MINIMUM OF ROOM TEMPERATURES DURING COMPARATIVE TESTS.

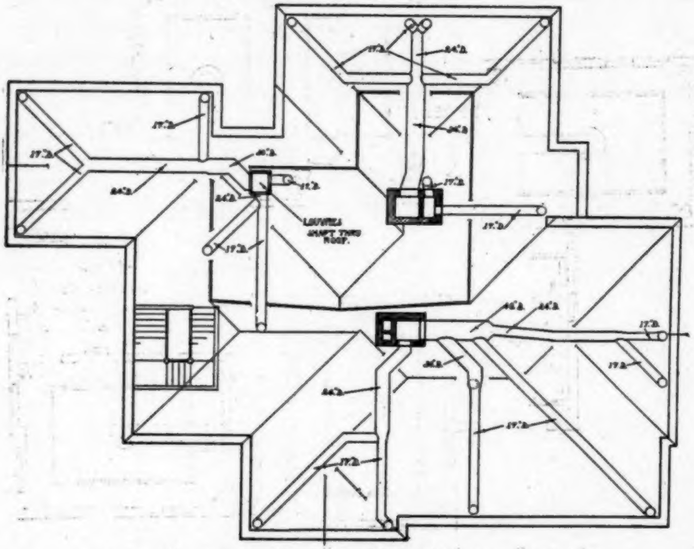
Room Number.	Northwest corner.	Northeast corner.	Southeast corner.	Southwest corner.
3	70–67	71–70	70–68	69–67
8	83–80	70–68	69–66	69–64

The temperature of the entering air as per twelve readings, expressed in degrees F., at 5-min. intervals, is given in the accompanying Table II:

TABLE II—TEMPERATURE OF ENTERING AIR DURING TEST.

Readings.	1	2	3	4	5	6	7	8	9	10	11	12
Room No. 3..........	74	70	72	73	70½	73	70	71	73	70	73	69
Room No. 8..........	68	76	109	76	98	72	80	94	68	97	65	83

A simple device for humidifying is located between the tempering stacks and the fan inlet, and is controlled by a humidistat, which is in a part of the building isolated from any influence or conditions in rooms Nos. 3 and 8. The relative humidity read-



PLAN OF THE ATTIC OF THE ROCKFORD SCHOOLHOUSE.

ings in room No. 3 showed 63 per cent, and in room No. 8, 54 per cent.

Observations of the relative time required to heat room No. 3 and room No. 8 to 68 deg. F. were taken, with heat turned on, at 7:30 o'clock, A. M.

From the accompanying Table III, giving the data compiled from these observations, it will be seen there was a margin of 35 min. in favor of room No. 3.

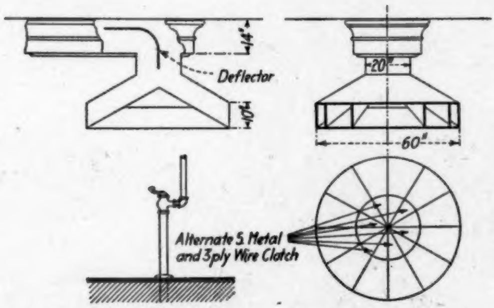
TABLE III—RECORD OF OBSERVATIONS ON HEATING ROOMS TO 68 DEG. F.

	Initial Temperature, Deg. F.	Rise, Deg. F.	Time.	Time required.
Room No. 3..........................	38	30	8.50 a. m.	1 hr. 20 min.
Room No. 8..........................	42	26	9.25 a. m.	1 hr. 55 min.

No little difficulty was encountered in operating room No. 3 with the same apparatus while meeting the requirements of the

remainder of the building because of usual high temperatures prevailing in plenum chamber. With the encouraging results obtained, the Hall School building was equipped throughout, during the summer of 1912, with the new method, and has been in operation since September 1, 1912.

The Hall School building is of brick, with wooden floor construction, two stories in height, with full basement. It contains five regular school rooms on each of the two floors, with wardrobes, recitation rooms, principal's office and corridors. The contents above the basement comprise 124,500 cu. ft. The building has a pitched roof with asbestos slate covering. One room in the basement is used for the mechanical equipment.



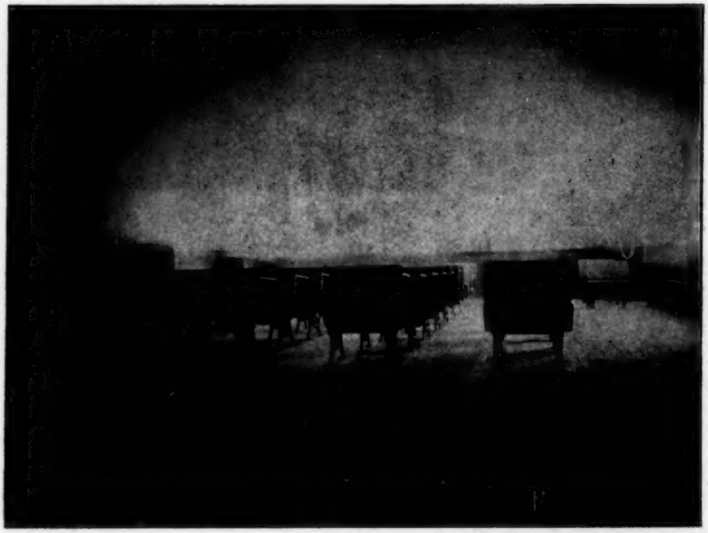
DETAILS OF AIR DIFFUSER AND VALVE CONNECTION TO CEILING COIL.

The power-house is isolated and constructed mostly below grade. It communicates with the mechanical equipment room in the basement by a concrete tunnel 4 ft. wide, 6 ft. 6 in. in height, and 17 ft. long.

The mechanical equipment comprises a multivane No. 13 fan, direct connected to a side crank engine, and operates at 174 revolutions per minute. All radiation and Vento blast coils are operated on the Webster system of vacuum heating. Johnson Service temperature regulation with intermediate control is used in each room. All galvanized ducts from the plenum chamber are of regulation design, with the exception of having been run to points where it was possible to take air delivery into the rooms from the front end of same.

Each of the ten schoolrooms is equipped as follows: A coil consisting of about three 1¼-in. pipes extends entirely around

the room approximately 5 ft. from the exposed walls and 6 ft. from the inside walls. These pipes are suspended by special hangers 20 in. below the ceiling, as shown in an accompanying illustration. These coils are supplied individually by a 1¼-in. riser from the main in the basement. The riser is equipped with a modulation valve about 34 in. above the floor, which gives it a slight offset. A single return takes care of the two coils in series from the first and second floors, respectively.



VIEW DURING STEAM TEST, SHOWING UNIFORM DOWNWARD DISTRIBUTION.

A galvanized-iron duct, 14 x 28 in., extends from the connection with the flues from the basement to a point central over the seating section of the room, from which the air is delivered to the room through an especially constructed diffuser, which breaks the velocity and directs the fresh air out in all directions over the breathing zone. This diffuser is located at a height to admit the air for ventilation to the room just below the stratum of the air at the ceiling, which is holding a uniform density by contact with the direct radiation.

The foul-air exits on the first floor are at the floor line in the four corners of the room, and are faced with sheet metal

frames and louvres, as shown in an accompanying illustration. The air discharges through these into vertical galvanized pipes, 12 in. in diameter, which extend upward through the second floor.

The foul-air exits on the second floor are located the same as on the lower floor, and connect with the foul-air, 12-in. round pipes from below, increased to 17 in. in diameter. These vent pipes lead to the attic, where they are gathered in groups, and

VIEW TAKEN IN ROOM 20 SEC. AFTER STEAM WAS TURNED INTO FRESH AIR DUCT.

discharge to the outer atmosphere. The sizes of these vent pipes were simply increased by multiples of the cross sectional area, the increase of resistance being relied on in the use of this method to maintain a sufficient static pressure in the rooms. All galvanized vent pipes below the attic are lathed and plastered on the outside. Only the exit frames are visible.

The principles on which this new method of heating and ventilating operates are as follows:

The direct radiation at the ceiling is the real vanguard of the heating agent for the room. The greater percentage of heat loss is prevented by close contact with the part of the room

which is most difficult to control, and is kept down to the minimum of difference in temperature between the floor and the ceiling. A warm-air stratum at the ceiling remains uniform in temperature and density. This influences the temperature of the room below without the air descending to the floor. The air for ventilation is previously warmed by Vento stacks in the basement, and enters the room through the diffuser, just below the warmer stratum of air at the ceiling, and is always of

VIEW IN ONE OF THE ROOMS EQUIPPED WITH DIFFUSERS.

slightly lower temperature than the air at the ceiling. This leaves a narrow range for variation in temperature of ventilating air to complete further the fine art of temperature control.

The air for ventilation is directed over the floor area of the room and is increasing in density at the moment of discharge, with the result that it falls to the floor as the forces of mechanical energy are exhausted. On arriving at the breathing zone, gravity plus static pressure forces the air out of the room at the floor line, producing a movement of air downward at a velocity of approximately 2 ft. per minute, with positive absence of lateral drafts or air currents. This condition is not disturbed

until below the top of the exits, and even then there is no noticeable air movement over the floor, due to the comparatively small exits drawing on a large volume. Each vent screen contains 1.1 sq. ft. clear area, which equals 4.4 sq. ft. for each room.

View of Room Vent Opening.

The accompanying Table IV gives the velocity and delivery records of all exits for ten 1-min. readings, taken after the system has been put in operation.

Table IV—Records of Velocities and Deliveries at Various Exits.

Room Number.	Northwest exit.	Northeast exit.	Southeast exit.	Southwest exit.	Total delivery, cu. ft., per minute.
1	270	384	326	400	1,518
2	390	394	396	350	1,683
3	390	400	450	314	1,709
4	332	354	460	446	1,751
5	364	360	334	332	1,529
6	336	346	345	342	1,506
7	352	406	334	350	1,586
8	434	428	448	366	1,843
9	344	328	356	384	1,553
10	412	336	370	282	1,590

The following is a summary of observations made while this system has been in operation:

A temperature of 83 deg. at the ceiling has been found to be sufficient as a maximum.

The temperature is controlled within a range of 1 deg. F., in all parts of the room throughout the breathing zone.

Air never enters the room above 71 to 74 deg. F.

which is most difficult to control, and is kept down to the minimum of difference in temperature between the floor and the ceiling. A warm-air stratum at the ceiling remains uniform in temperature and density. This influences the temperature of the room below without the air descending to the floor. The air for ventilation is previously warmed by Vento stacks in the basement, and enters the room through the diffuser, just below the warmer stratum of air at the ceiling, and is always of

VIEW IN ONE OF THE ROOMS EQUIPPED WITH DIFFUSERS.

slightly lower temperature than the air at the ceiling. This leaves a narrow range for variation in temperature of ventilating air to complete further the fine art of temperature control.

The air for ventilation is directed over the floor area of the room and is increasing in density at the moment of discharge, with the result that it falls to the floor as the forces of mechanical energy are exhausted. On arriving at the breathing zone, gravity plus static pressure forces the air out of the room at the floor line, producing a movement of air downward at a velocity of approximately 2 ft. per minute, with positive absence of lateral drafts or air currents. This condition is not disturbed

until below the top of the exits, and even then there is no noticeable air movement over the floor, due to the comparatively small exits drawing on a large volume. Each vent screen contains 1.1 sq. ft. clear area, which equals 4.4 sq. ft. for each room.

VIEW OF ROOM VENT OPENING.

The accompanying Table IV gives the velocity and delivery records of all exits for ten 1-min. readings, taken after the system has been put in operation.

TABLE IV—RECORDS OF VELOCITIES AND DELIVERIES AT VARIOUS EXITS.

Room Number.	Northwest exit.	Northeast exit.	Southeast exit.	Southwest exit.	Total delivery, cu. ft., per minute.
1	270	384	326	400	1,518
2	390	394	396	350	1,683
3	390	400	450	314	1,709
4	332	354	460	446	1,751
5	364	360	334	332	1,529
6	336	346	345	342	1,506
7	352	406	334	350	1,586
8	434	428	448	366	1,843
9	344	328	356	384	1,553
10	412	336	370	282	1,590

The following is a summary of observations made while this system has been in operation:

A temperature of 83 deg. at the ceiling has been found to be sufficient as a maximum.

The temperature is controlled within a range of 1 deg. F., in all parts of the room throughout the breathing zone.

Air never enters the room above 71 to 74 deg. F.

All rooms show an absolute sense of proportion and freshness.

There is no noticeable effect on the conditions of the rooms caused by the glass exposure, but tests show a slightly higher rapidity in downward movement of the air from the glass surface several inches into the room.

The air distribution is positive and under normal schoolroom conditions the aerial envelope around any individual is moving downward and does not come in contact with that of another but is discharged from the room without rising again to the breathing zone.

There is an entire absence of drafts or currents, and the cold surface of desks and furniture does not contrast against high temperatures of atmosphere surrounding them, as is often complained of in other systems.

During the week of December 15 tests were conducted by the school authorities to determine the efficiency of this system. The temperature was uniformly 68 deg., and the humidity at 58 per cent. To demonstrate that no cross currents existed, live steam was introduced into the room through the diffuser in the ventilating system. The steam distributed equally throughout the room and dropped gradually toward the floor, like a blanket, until it reached the level of the exits through which it escaped. Another test comprised the suspending of a large number of silk threads about the room with small pieces of paper attached to the end of each. The absence of any swaying of these pieces of paper showed that there were no cross currents generated by the ventilating system.

Some observations have been made of the amount of leakage. Readings of static pressures were taken with Ellison's differential draft gauge, which, being balanced at zero outside of the building, showed 0.03 in. pressure when connected with the inside of the room. All windows are provided with grooved weather strips, and are more than ordinarily tight, yet all these tests where steam was turned into the room showed a decided leakage outward, particularly between the meeting rails of the sash, which were purposely pried slightly open to allow a chance to observe if leakage was inward or outward.

Economy of operation is evident, but as yet no effort has been made to determine any facts or comparative saving. The

studies of this method are incomplete at this time, owing to not having the time or opportunity to continue an uninterrupted study.

The consensus of opinion with the members of the Board of Education is that the installation at Hall School is a decided success. Teachers are enthusiastic. Pupils show no signs of restlessness toward the close of the school day. The school principal claims a noticeable improvement in the work done by both teachers and pupils.

ADDENDA TO PAPER PREPARED BY CLINTON E. BEERY.

At the time of preparing the above-mentioned paper, which simply covers the installation in Hall School Building as completed to date, it did not occur to the writer to go beyond the actual point to which my system has been developed in actual practice. However, on giving more serious thought to the matter of a subject being up for discussion it appeals to me that it would be interesting to the members of the Society that I should submit the theoretical continuation of the method. If it be demonstrated in operation that it was desirable to put the same into practice. That is, to arrange to thoroughly flush rooms and thereby discharge to the outside atmosphere any gases of harmful nature that might rise up out of air at breathing zone, and enrich the stratum of air at the ceiling to a point where the same would have any undesirable influence on the room.

A brief description of the means to this end, as contemplated in my theory is as follows:

A second air exit is provided in each corner of the room at the ceiling line, directly over exit at floor. Exit at floor and ceiling thus communicate to galvanized iron pipe discharging to outdoor atmosphere. Exits at top and bottom are provided with pivoted louvres with shutter bars, which are cross-connected between shutter bar of top and bottom sets. A small diaphragm motor, operating on air pressure from temperature control system keeps lower exit open and top exit closed when rooms are occupied and ventilation with air distribution is desired. By operating a simple three-way cock on air line in apparatus room, the bottom exit is closed and the top exit is opened which clears

the room of air at ceiling, thereby flushing out the room and giving an entire new air content.

DISCUSSION.

Chairman Hale: Gentlemen, the paper is before you for discussion. There is no question at all but what this apparatus is unique in its construction. This heating and ventilating is a system and a method for diffusing the air. The illustrations show the condition of the air as steam was admitted into the room through the duct, and in the discussion Mr. Beery will probably explain to you the methods by which this test was made, and the volume of steam used at the time and what effect it had on the room; all of which illustrates the downward direction of the air as it is forced through the diffuser and finds exit through the outlets. I understand there was no exhaust fan whatever, it was simply a plenum condition.

Mr. English: I would like to ask Mr. Beery if it was a distinct advantage to have the additional outlet at the ceiling in the exit. I believe Mr. Macon knows that at one time all the New York schools had exits at the ceiling and they were discontinued. They were considered to be a disadvantage. If Mr. Beery will explain what advantage was gained by such outlets I think it would be very edifying to the members.

Mr. Timmis: Mr. Beery explains that there were no drafts in the room heated that way when the temperature of the incoming air was slightly above that of the maintained temperature of the room, and when the velocity of the incoming air was low. I would like to ask him how he accounts for the fact that there is no drop in temperature near the window, that he has practically static conditions. We observe in practically all our work that when you have a static condition the temperature near a window is very much less because of the descending drafts. I would like to ask him if he made any tests for drafts near the window.

Mr. Macon: I would like to ask Mr. Beery what amount of relative humidity he was able to use in the rooms in zero weather? From his paper it looks as though he had a very high percentage of humidity, and as though the windows would be dripping with moisture.

Mr. Davis: I want to ask Mr. Beery if he tried putting the direct radiation under the windows near the floor and compared it with putting it on the ceiling? According to his statement he has, in a room 26 by 31, about 350 feet of 1¼-inch pipe; and that must take care of the heating, because he states that the incoming air was only about 70 or 75 degrees.

Mr. Willard: I want to ask in regard to the thermostat location on the side wall and its relation in connection with the coils, or in regard to the temperature of the air from the fans, whether that was under automatic control.

Mr. Turno: I want to ask Mr. Beery if he does not think the same result would be obtained by bringing in the warm air at the top of the room, say at 85 degrees, thus simplifying the apparatus and doing away with the direct radiation of that room?

Mr. Barron: Mr. President, my question is very much in the same order. It seems to me that a simple hot blast system with thermostat regulation and humidity control on it, with the ceiling coils eliminated, would produce as good results at less initial cost and probably less cost of maintenance. But I would like to ask Mr. Beery if he experimented in that direction, and if he has any knowledge of systems of that character which he has compared with his own.

Mr. Ellis: I do not want to ask Mr. Beery any question, but his statements here are somewhat remarkable. I happened to be aware of these experiments a year ago. I want to corroborate all the statements that Mr. Beery has made. I want to say that last January Mr. Beery asked me to come out to see some experiments that he was making in a new arrangement for a heating and ventilating system. At that time he had equipped one room in the school with this system, although he had not worked out all the details that he now describes. The school board had allowed him to modify the heating and ventilating arrangements in one room to conform to his ideas. I visited the school on a cold day when the thermometer was about two or three degrees below zero. The room that was equipped was on the first floor, and there was another room exactly like it on the floor above, of the same size also, with the same location of inlet and outlet, the same method of service, except that the air was taken in at an inlet in one wall, and out of an outlet in the other. There was direct radiation

between the windows in the room he had equipped, but this radiation was removed, and this coil, going around the ceiling, was put in as described. I spent the afternoon there and made quite a few tests. I was smoking constantly, and the difference between the two rooms was very noticeable. There was a decidedly lower temperature around the windows in the room with direct radiation beneath it. There was hardly any appreciable difference in temperature in any part of the room that had this coil around the ceiling. Apparently in front of the windows it was absolutely as warm as it was in any other part of the room. I was dumfounded. I had no anticipation of finding such an entire contradiction of previously conceived theories. The smoking which I was doing seemed to indicate that there was a complete circulation of air in every part of that room; whereas, in other rooms directly over it, of the same size, the smoke would hang in the corners. I make these statements so that you may have some little corroboration of what Mr. Beery has told you in his paper.

Mr. Whitten: In confirmation of what Mr. Ellis has just said, in observing air currents in schoolrooms, in many tests I have found that with the radiation under the window there is a rising body of warm air from the radiator, which means a contrary falling body of air from the window, and there is a conflict of currents. The warm air from the radiator is deflected into the room. But with the radiation moved away from the window or removed altogether and the warm air supplied from above, either from the regular method of supply, or I should imagine from this source as described by Mr. Beery, there is a constant falling of air in front of the window, and the colder the weather and the colder the window, provided it was tight, as described in this particular case, the more rapid that flow. You cannot get a vacuum up in the corner of a room next to the ceiling above the window; and, if the counter current is not set up by the radiator underneath, you will get warmer conditions in front of a window every time.

Mr. Snow: Mr. President, I would like to ask Mr. Beery if the tendency of the ventilating duct placed in the exposed corners of the room is not to draw out a considerable quantity of the fresh air which has just fallen by coming in contact with the chilling walls and the floor and drawing that air along the lines

which run along the exposed walls before that air has really penetrated into the seating spaces; and also to ask Mr. Beery if the placing of the coils on the ceiling, as in mill heating, does not tend to cause a recirculation and to assist in stripping that air from the seating spaces. It seemed to me that any of the ventilating ducts placed in the corner of the room would take out a considerable quantity of the fresh air just as it had fallen along chilling walls and the floor before it had had an opportunity to do its work in the vicinity of the seating spaces.

Chairman Hale: If there are no further questions or remarks to be made we will ask Mr. Beery to reply as far as possible to the questions that have been asked, and if he does not remember all the points we will ask the question again to assist him in every way.

Mr. Beery: Mr. Chairman, I have been quite unable to get all those down. The first question that was asked was a description of the humidifier. All I used was a simple iron pan, with a submerged pipe in the pan of water, with a series of petcocks along the pipe, and we used low pressure steam on that and a thermostatic valve that allows the saturated steam to pass off with the air. We have not paid any particular attention to the science of humidifying the air; we just fixed up a little something with the means at hand. As a matter of fact our time has been so short, and I have so many other things to do, that I have not made a series of scientific studies on the apparatus.

The second question was, I believe, if the exit at the ceiling was desirable. My answer to you is, with this system decidedly not. We haven't any. We were not equipped with them, and my experience has been such that if a room is so equipped it will be only for the purpose of getting a comparative result with that of a room without them. My idea was that these exits at the ceiling are never open during any time when the rooms are occupied for school purposes. I can see a time, though, when it is possible that such outlets might be a benefit. I know in our town sometimes when contagious diseases afflict the school children it becomes necessary to fumigate rooms. We use formaldehyde for fumigating and spread the smoke throughout the room and, at such times, if you can open such exits at the top and bottom and use your fan and pass air through your room, you will very quickly get rid of the odors from the formaldehyde

that was used for fumigating; but as far as being better for ventilation it is my judgment that they are of no advantage.

Now as to down draughts. I do not believe I can explain that any better than Mr. Whitten has. But my experience is that if you live an hour in an atmosphere that is of the proper temperature you do not find any noticeable influence of a lot of glass or plaster wall at your back or side. I have repeatedly sat on the edge of the window sill in cold weather quite a length of time without feeling any draught from the windows.

Replying to the question in reference to the relative humidity, I did not take the humidity readings myself. They were taken by Professor A. C. Norris, of the high school faculty. He is the director of the medical laboratories in our high school. He is quite interested in those matters, and he took his instruments and took his own readings and gave me the results.

At this particular time we had a humidistat control, but it has never been adjusted with any idea of maintaining relative humidity. We went largely by our feelings; we have not as yet tried to draw the line very close on the question of humidity.

Chairman Hale: In reference to the overhead coils, can you show that there is any marked advantage by putting the overhead coils in the building?

Mr. Beery: I say there is a decided advantage. I believe that there isn't anyone here who has fully appreciated what I would like to convey to you, and that is the point that we are reducing our temperatures at the ceiling by means of putting radiation up there. I am not trying to heat the room with radiation at the ceiling, but I am trying to prevent high temperature up there, which is unnecessary. I am working backward with my radiation at the ceiling instead of working forward. With the temperatures outside ranging around 45 and 50 we cannot use our radiation at the ceiling. We do not need it. Because you all know that it does not take much heat to take care of it. When the temperatures get down to 10 above or lower, the radiation up at the ceiling is a decided advantage.

Chairman Hale: Mr. Snow asked in reference to the peculiar position of your vent flues, and whether there was not a possibility of the down draughts being noticeable at the floor and the air passing from the window directly to the vent flues, instead of being mixed up in the general diffusion of the air.

Mr. Beery: Well, I want to assure you that I will try to make all my answers conservative and honest as I understand them, and as I have had experience with this method. I am convinced that there is a rapidity of air movement downward on all the exterior walls of the room. That I am quite sure of. As far as having the smoke or current along the side of the room on the floor, or moving toward the exhaust, there might be a current passing down this aisle to get to the exhaust register.

Mr. Snow: Would not the current follow the line of least resistance at the floor line, right along to the corners of the room, rather than come back into the seating space where the children are seated?

Mr. Beery: I want to say this—I don't know whether it will answer your question or not: there is a steam test referred to, but that, to my mind, does not amount to much. We suspended bits of tissue paper about two inches long by half an inch wide with a silk thread fastened in the middle of them. They were suspended so they hung about six inches above the desk top, with about thirty-six inches of silk thread above; and at that point there was nothing tending to show that the air was going any other way than downward below that point. There is no doubt but what there is a tendency to have a stronger air movement in the aisles when you get below the desk tops. But they are not noticeable to any extent. The air has passed the breathing zone at that time, and it does not produce discomfort, and we have never had a complaint of anyone having cold feet. They all seem to be perfectly comfortable. There is no question but that the current takes the course of least resistance, and there probably will be an opportunity to make some improvements. I am frank in stating to you everything I have done in this installation some of the design was purely experimenting. I wanted to try certain things out to see how they would work.

There was no tendency to short-circuit the vent registers. To determine this, we took a low pressure steam line and turned it up in the bottom of the flue where the air was passing upward in the duct and passed it into the center of the room. We turned in sufficient steam so it would just carry along nicely with the passage of the air and not add any more than necessary to the velocity of the air. We did not diffuse it as an injector, just simply put in enough. We could get the room filled with steam.

The illustration in the paper shows the detail of everything in the room. The experiment is not altogether striking in the illustration, but it is striking in practice. When the air blanket got down to the breathing line there was no reason why the air would not follow the steam over to the four corners. When the steam got down to this level you could pass under it; you could step under and go down the aisles all over the room; but you could not find a place in the room where the density was not equal, you could not find a spot that was not well supplied. Absolutely no lateral movement of air occurred till you got below the desk tops.

Mr. Franklin: I would like to ask a question. What was the basis of computing the amount of direct radiation in the room?

Mr. Beery: I have previously answered that question indirectly. It was like the case of the exits: it was just an experiment. It was just a matter of judgment. I have no data that I could check against.

I took the position that at any time, except in bad weather, we would hardly need the ceiling radiation. When the temperatures are above 30 outside it is very difficult to do anything with this radiation, for the simple reason that, with three coils, all connected to one supply, we could not open the modulation valve far enough to get the circulation around the room. One mistake we made was in not having separate inlets and valves for each of the coils. We might have put on steam enough to get around one coil, but as it is, when the temperatures were above 30 or 35 outside we could not cut off enough of the coil to justify their use.

Mr. Teran: I would like to ask Mr. Beery what temperature he obtained at the ceiling when he did not use the air for ventilation.

Mr. Beery: When the temperatures were around 20 or so outside it would take us about four or five hours with the amount of radiation at the ceiling to get the room up to 70 with the pupils in their seats. The influence was very slow in the room. It took a long time to get the room heated from the ceiling.

Mr. Davis: Mr. Beery states that when the temperature got up to about freezing, 30 to 32, that he was compelled to shut off the coil at the ceiling. I would like to ask him if he made any experiments at such times with the circulation of air from one outlet. What results did you get then?

Mr. Beery: I think you misunderstood me. I said that we did not get enough if any benefit from the coils that would justify their use. If we were never going to have a temperature below freezing I question whether coils would be of any advantage.

Mr. Davis: Did you try a ventilation system without the coils, and, if so, what results did you get?

Mr. Beery: There was no particular observation made without the coils being used. I found my system would not work so well without the coils, that was all. I had no time to make observations. I could not be in the building maybe more than once or twice a week during this time. I expect to make such observations later.

Mr. Willard: May I ask a question in regard to the thermostat? I was interested, just as a previous speaker was, in regard to the air, the line of temperature and where the wall thermostat would be located; if the flow of air fell in temperature how it was controlled. Also whether the coil was controlled by the thermostat so it would shut off with overheating, so that the proper temperature would obtain at the seating line.

Mr. Beery: I think I could answer your question by saying it is easier to illustrate the method that we were using for experimental work. The heat screen was about four or five feet from the ceiling on the left of the room. The exit was just to one side of it in the next flue and at the floor line. The thermostat was located about in the center of this wall, and would be about fifty-four inches from the floor. That is the arrangement of Room 3, as we operated it; and Room 8 was identical, with the exception that the exit was on the opposite side of the seats. All the thermostats are approximately fifty-four inches from the floor.

CCCVI.

IMPROVED AIR CONDITIONS IN A BOSTON RESIDENCE.

BY FRANK IRVING COOPER.

One of the latest fields for investigation in the engineering profession is the question of the differences between the beneficial quality of indoor and outdoor air, and in it we are confronted by the enormous difficulty which always besets any truly novel investigation, that is, ignorance of the goal toward which we are traveling. We know the air conditions at present are far from good, but we are also uncertain as to what would be ideal conditions, and nothing but scientific experiment can determine them.

In this experimenting the members of the medical profession have found their interests to be in common with those of the engineers, and their efforts have resulted, not only in great advances in scientific theory and discovery, but also in the widespread awakening of public interest, which is always necessary for the successful carrying out of any reform.

That the public is really awakened is shown by the readiness with which huge corporations spend large sums for the purpose of bettering air conditions. A notable instance is seen in the great transportation companies of New York; everywhere we find huge and costly fans and elaborate devices for the proper ventilation of the tunnels. In London in the tunnel of the great London Railway there is an elaborate ozone apparatus.

The results obtained from the equipment in these and many other instances have shown that air conditions can be produced that will increase the comfort of living, even if the medical profession is uncertain as to the effect of these changed air conditions on the health and longevity of the human body.

What is needed for further improvements is that the doctors shall point out the desired conditions to the engineers, as it is

at bottom a question of public health. The engineers can do little beyond mere experimentation, the doctors must analyze the effect of certain conditions of that air on the health, and, as they have been ever ready to do in the past, point out the path for future work.

Recently at the suggestion of physicians we have designed several plants for conditioning the atmosphere in dwelling houses and perhaps one of the most novel is the plant for Mr. Albert C. Burrage in his Boston residence on Commonwealth Avenue. This plant, although completed recently, seems so successful that a description of it should be of interest. It was desired to better the air conditions of certain rooms in this residence, and this meant introducing a fixed number of cubic feet of air, which should be cleaned, warmed, humidified, and should contain an added amount of ozone.

These conditions under ordinary circumstances would be comparatively easy to accomplish, but in this case the plant had to be installed in the space between the top story and the roof of the house, a working space of only 3 ft. in height; was to be controlled from a room three stories below, and the only means to the desired end were electricity and cold water under pressure.

Under usual conditions of cost the use of electricity would have been prohibitive; the Edison Company of Boston, however, furnish current for power and heating purposes at one-fifth the cost of current for lighting. The Simplex Electric Heating Company, of Cambridge, built for us a special electric radiator in three units; the radiator was guaranteed to dissipate enough B. t. u. to heat 200 cu. ft. of air per minute from zero to 70 deg. F.

The number of cubic feet of air is controlled by a multivane, variable speed electric fan; the air is drawn from above the roof through a hood screened to prevent the admission of paper or leaves; there is also a fine screen near the radiators to remove smaller floating particles; the air then passes through the electric radiators, then through a water bath in the humidifying chamber, where vapor created by electric immersion coils fills the air to the amount required to give the desired amount of moisture content in the conditioned rooms below; dust particles are entirely removed by the water bath, which can be renewed as often as desired.

There is an atomizing spray for washing and cooling the air; large particles of water floating in the air current are removed by inserting copper wire screens of a special Dutch weave, which entirely clears the air before it passes through the fan. Beyond the fan in the main duct is placed an ozonair apparatus, which gives an additional quantity of ozone in amount desired.

The control of the electric radiators and the regulation of the evaporating coils is made by the Powers System, which automatically throws in or pulls out the proper electric switch as occasion requires. An air pressure of 15 lb. per square inch is required to operate the switches. In this case we installed a water-driven compressor of the Powers make.

The main electric heater was designed by Mr. Hewett, of the Simplex company. It is made up in three sections, similar to the different units of a steam fan system of heating, each unit being separately controlled; but where a diaphragm valve is used on a steam plant here automatic switches are employed to make or break the electric connection which completes the circuit for supplying current to the different heating sections.

The electric heater was designed to heat 200 cu. ft. of air per minute from zero to 70 deg. F. It consists of wire coils made up in the shape of a close spring ½ in. diameter and 14 ft. long. In the center of the spring is a stout asbestos cord. The spring is stretched out slightly and fastened to each end of the cord, thus keeping the convolutions of the cord separate. The spring was then looped over porcelain insulators mounted on an iron skeleton. Winding the coils in this way and using metal of low resistivity permitted a large number of coils to be used, thus obtaining a large radiating area on the surface of the wire, which means that they would dissipate their heat and operate at low temperature, thus reducing oxidation to a minimum.

There were three sections, each consisting of 4 coils, as described, connected in multiple. Each section was separate from the other electrically and was of 2 k.w. capacity on 220 volts. All three sections were, however, mounted on a single strap iron frame and covered with an expanded metal guard. Insulation between element and guard was tested to 1,000 volts. The complete heater was designed to go in a space 28 in. long, 12 in. high, 16 in. wide. The heater has given entire satisfaction.

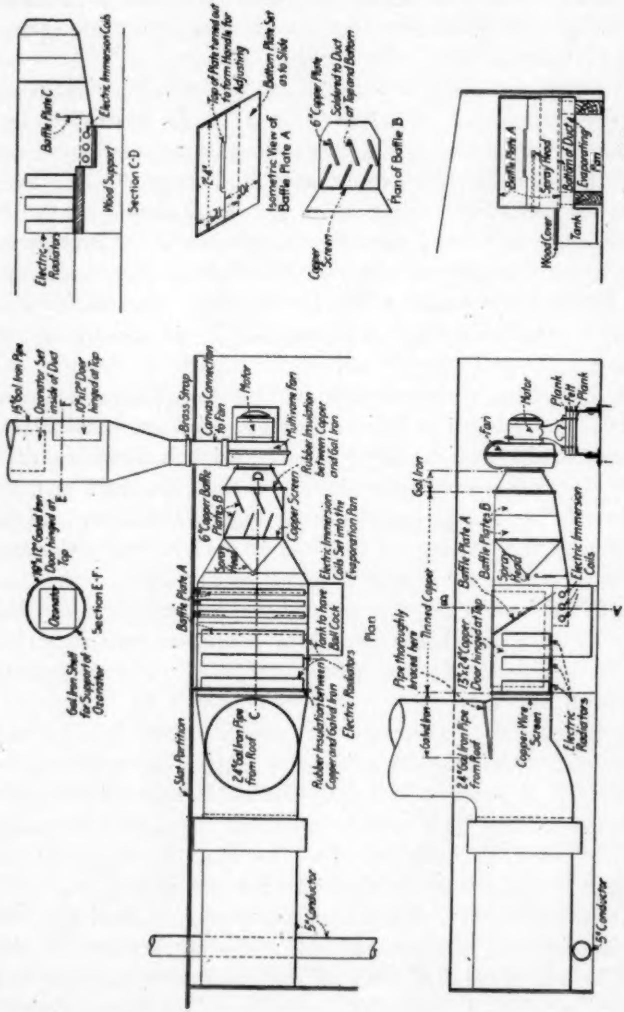
The cold air enters from the roof through a galvanized iron

duct. In traveling to the first section of the heater it passes over a cold air, expansion type, duct thermostat, which is set for 40 deg. In mild weather, or at such times as the incoming air is above 40 deg. in temperature, the first or outside section of the heater is automatically cut off.

The second and third sections of the heater are controlled by one graduated acting thermostat placed in the apartment supplied by air from this plant. It is located at the fan outlet, where incoming air passes freely over it, thereby allowing close regulation. This thermostat is the usual one employed by the Powers company for graduated damper work. Through its capability to graduate air pressure delivered to the second and third diaphragm motors, which are supplied with differential springs, a range of 2 deg. is maintained by the use of one instrument.

The diaphragm motor controlling the second section of the heater is supplied with a pair of springs which are considerably weaker than those on the third motor, so that it takes less pressure to throw the second switch than it does the third one, the difference being enough to allow two degrees variation between the opening and closing of the two sections. The graduated thermostat is adjustable over a range of 20 deg.—from 60 to 80—and can be set for any temperature between these points by the use of a detachable key which is used to turn a marked dial over a graduated scale plainly shown on the cover of the instrument.

As explained above, the moisture is admitted to the air which has passed through the main heater. This is accomplished by three electric immersion coils placed in the bottom of an evaporating pan. These coils are kept covered with water automatically; they were designed by Mr. Hewett and are of the type such as are used in electrically heated steam boilers and large capacity water heaters. They consist primarily of a wire wound in spring form about as described in the air heater. In this case, however, a notched piece of mica is put in between each convolution. This is put in in such a way that does not permit it to fall out. The convolutions are therefore insulated from each other, and, as the mica extends beyond the periphery of the coil, it insulates the heating element from the tube in which the element is placed. The mica dividers each have a hole in



PLAN, ELEVATION AND DETAILS OF THE ELECTRIC AIR HEATING AND CONDITIONING APPARATUS

the center, which permits a 3-16-in. rod to be pushed down the center of the coil, making it a straight rigid unit. Terminal blocks are attached at each end; the central rod forms the electrical return, thus permitting the heater to have its supply terminals at one end.

This unit was slipped into a brass tube, 1¼ in. outside diameter, No. 16 gauge, which had one end sealed and the other provided with a flange and threaded for a nut, which permitted the tube to be locked into the wall of the vessel, resting one end on the bottom. The joint was made tight by a gasket.

There are three heaters, each to evaporate about 4 lb. of water per hour; each heater was of 1,100 watts, 220 volts, single heat, and was 27 in. long. The wire used in the water heater was altogether different from that used in the air heater. The number of heat units dissipated per unit area on the water heater is large and the element within the tube runs very hot. The wire is a nickel chromium alloy which will stand very high temperature without oxidation. Most forms of insulation would break down under such a condition, but the large number of mica washers which stand edgewise to support the coil easily stand up under the work. The current of this heating coil is automatically regulated by a Powers Hygrostat placed in the living apartments on the same panel with the thermostat which controls the temperature.

It was impossible to use lengths of galvanized iron pipe, as is the custom on automatic control work, so flexible armored lead tubing was used to supply thermostats and hygrostats with air pressure and also to make connections between these instruments and the four diaphragm motors used. The tubing was extended from the air storage tank, along the under side of the roof, to the flue that leads to the room—from where it was dropped into the flue and connections made to the controlling instruments by running the lines on the inside of a cabinet—thus exposing none of it in the rooms. From the thermostats and hygrostats return lines were carried back the same way to the different diaphragm motors. Very little cutting and no patching was necessary to install this system, which is working to the satisfaction of all concerned.

The atmosphere is pleasant and restful, and the effect of the

conditioned air is already distinctly beneficial. While it is too early to declare with positiveness that the proper adjustment of heat, moisture and ozone has been reached, we have all of these under control and shall be able to meet any particular requirement of the attending physician.

CCCVII.

AN ANALYSIS OF A COMBINATION HEATING SYSTEM.

BY FRANK K. CHEW.

There should be found in the publications of the Society records of all methods of heating and ventilating buildings, particularly those used for homes, and it is the object of this paper to fill one vacancy by giving an analysis of the combination system, using both warm air and hot water for ventilating and warming. The building has open fireplaces, a provision which can be widely recommended as a valuable auxiliary to both ventilation and heating. The accompanying plans give the arrangement of the building, which is a farmhouse, remodeled to serve as a summer residence, but provided with apparatus, as indicated on the plans, to make it comfortable at all seasons of the year. It will be noted that it is the reverse of compact, being extended, and putting the maximum load on any system of heating. To buildings of this type, the combination system is peculiarly adaptable, for when the air supply is taken from out of doors, a superabundance of fresh warm air is furnished, and the hot water circulates through radiators in the more distant and exposed parts.

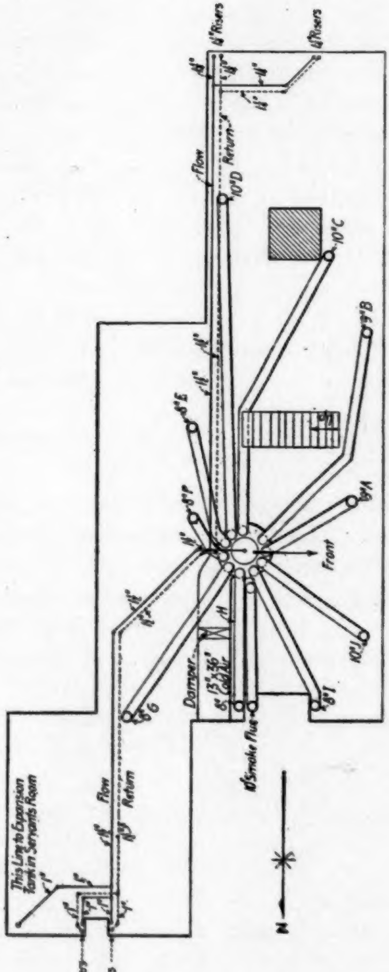
It will be noted that Chamber A, at the south on the second floor, is over an open porch, and is provided with two radiators, and that the servants' chambers, over the kitchen on the extreme north, also have radiators, and all are generous in the surface apportioned to the work to be done. The accompanying table gives the dimensions of the various rooms, with their contents, wall exposure, glass surface, equivalent glass surface, diameter, and area of warm pipe, radiator surface to space heated, and the equivalent glass surface. The pipes leading to the different rooms bear letters corresponding to those given

in the table. For the pipes in the table marked with an asterisk, the general proportions have not been figured.

The table shows that the space heated amounts to 22,057 cubic feet, and that the exposure amounts to 1,212 square feet, of equivalent glass surface. The building is of frame construction, of the type for which the heating contractor provides apparatus with wonderful accuracy as regards heating capacity, and without laborious calculations, employing the expert knowledge gained in and sharpened by individual experience. The apparatus has been subjected to the test of actual use, and the bill has been paid, so there is the usual evidence that the judgment of the engineer was correct and the service satisfactory.

The heat required is furnished by a warm-air furnace in the combustion chamber of which, about 6 inches above the fire, is suspended a hollow disk water heater. The furnace is a No. 158 Crusader, with a 58-inch galvanized casing insulated with asbestos proper and an inner lining of corrugated bright tin. It has a so-called square fire pot, 20 in. square inside at the bottom, and 31 in. in inside diameter at the top, and 14 in. deep from the grate to the bottom of the feed chute. The grate is of the triangular bar type, setting 1 in. below the bottom line of the fire pot, to give free entrance to the air and allow the ashes to fall away freely. The bars of the grates may be operated independently and clear the fire pot, so that there are no dead corners or ash accumulation which is calculated to reduce the heat transmission from the fire pot. In addition to the provision for admission of air to the fire, there is a 40 per cent. free air space through the grate.

Above the fire pot, which is corrugated to increase the heating surface, there is a corrugated combustion chamber, 31 in. in diameter at the bottom, and extending upward 13 in. to a central combustion dome 21 in. in diameter, and standing 16 in. high, with a 20 in. diameter at the top, or just enough taper to draw from the sand in the molding. A flue leads from this combustion dome to an annular steel drum, or radiator, 16 in. high, the inner wall of which is curved to a 36 in. diameter circle, and the outer wall to 48 in. diameter. There is a vertical portion in this drum, so that the products of combustion must make a complete circuit of the flue, which is 6 in. wide, and 16 in. high, to



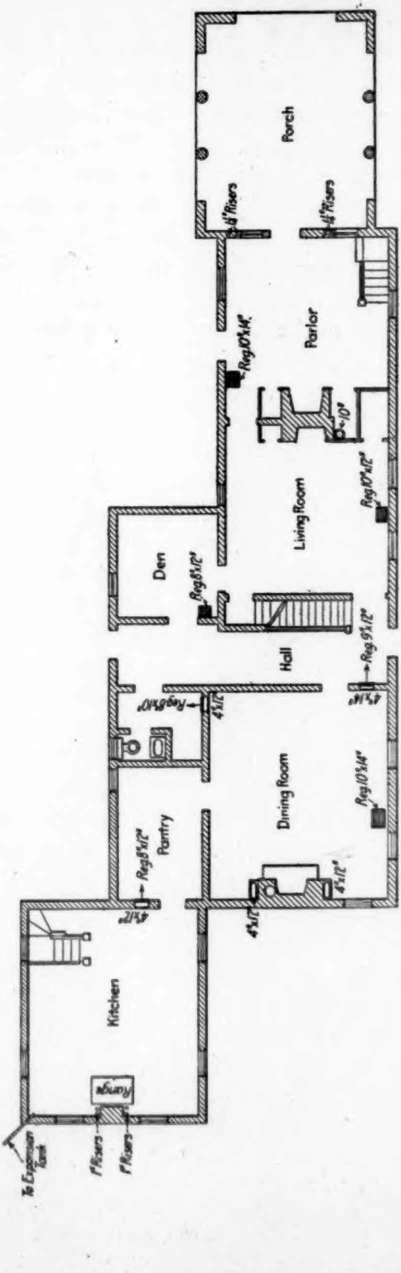
CELLAR PLAN OF THE RESIDENCE.

reach the 9 in. smoke pipe. An approximation of the surface exposed in the furnace is given in the accompanying table:

Square fire pot	9.0 Sq. ft.
Combustion chamber . .	11.0 Sq. ft.
Combustion dome . . .	4.1 Sq. ft.
Combustion dome head .	2.2 Sq. ft.
Inner drum	12.5 Sq. ft.
Outer drum	17.4 Sq. ft.
Top drumhead	5.5 Sq. ft.
Bottom drumhead . . .	5.5 Sq. ft.
	67.2 Sq. ft.
Feed chute, smoke collar, etc.	2.8 Sq. ft.
	70.0 Sq. ft.

The last addition has been made for ready calculation, making the surface 70 sq. ft., and it is quite probable that careful measurement would discover that effective heating is exposed to the extent of 70 sq. ft., even if the surface of the drumhead, and the combustion dome head were omitted from the table. The furnace has the Boynton check damper, and has an ashpit damper adapted for connection with it in a thermostatic draft control system. The grate has an area of 2.8 sq. ft. The square fire pot has a capacity of 4.6 cu. ft., and for 248 lb. of coal, assuming a cubic foot of anthracite coal weighs 54 lb. Assuming a charge of 248 lb. would last 8 hours, with 20 per cent. to rekindle another charge, about 25 lb. per hour would be available; and, assuming 8,000 B.t.u. would be available for heating in the construction described, the heater would provide 200,000 B.t.u. per hour. This would mean, with a grate of 2.8 sq. ft., a consumption of about 9 lb. of coal per hour. The furnace is connected by means of a 9-in. galvanized iron smoke pipe, with a 10-in. inside diameter tile flue, in a chimney that is about 30 ft. high to the top. This is the heat-producing equipment.

The work to be done may be calculated from the table. The portion warmed by the radiators contains 4,166 cu. ft., and exposes 344 sq. ft. of equivalent glass surface. It is assumed that



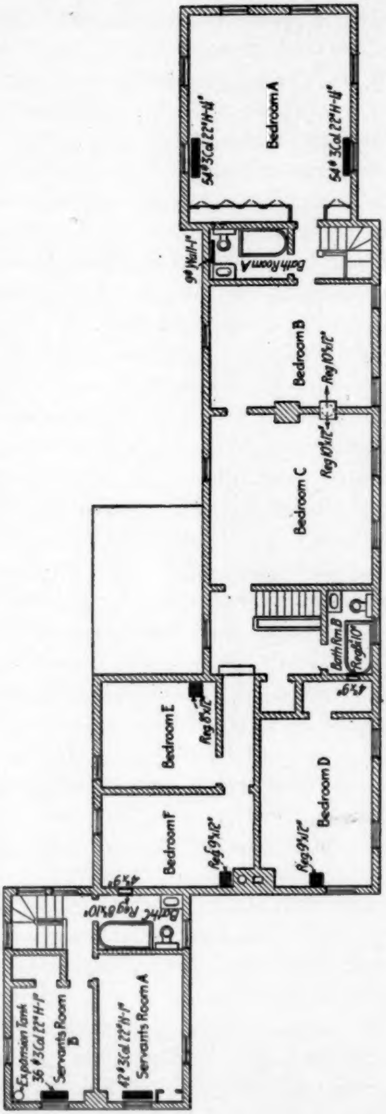
First Floor Plan of the Residence.

each square foot of E. G. S. loses 85 B. t.u. per hour, when an indoor temperature of 70 deg. is maintained, with an outdoor temperature of zero. Hence $344 \times 85 = 29,240$. It is assumed that there will be one air change per hour, and that the air must be raised from zero to 70 deg., and as 1 B.t.u. will raise 55 cu. ft. of air 1 deg., the heat required will be $4,166 \div 55 = 75.74$, and $75.74 \times 70 = 5,302$ B.t.u. The total heat that must be supplied by the water radiators is $29,220 + 5,302 = 34,522$ B.t.u.

The water heater exposes 5.5 sq. ft.; and $34,522 \div 5.5 = 6,276$ B.t.u. that must be absorbed per square foot per hour from the fire and transmitted to the water circulating through the heater. There are 195 sq. ft. of radiation and $34,522 \div 195 = 177$ B.t.u. which would have to be given off per hour by each square foot of radiation with these heat requirements, and not allowing for surface in exposed piping. If no change of air is figured, the calculation would be $29,220 \div 195 =$ practically 150 B.t.u. per hour per square foot of radiation.

The portion of the house warmed by warm air contains 17,891 cu. ft., and exposes 874 sq. ft. E. G. S. The heat loss is $874 \times 85 = 74,290$ B.t.u. per hour, and must be offset by the heat brought in by the warm air. Assuming the air enters at a temperature of 140 deg. and escapes at a temperature of 70 deg., the amount of air necessary to offset the heat loss is calculated thus: For every time the air is changed, the 17,891 cu. ft. will give up in cooling 1 deg., $17,891 \div 55 = 325$ B.t.u. As the air cools 70 deg., the total amount of heat given up for each air change is $325 \times 70 = 22,750$ B.t.u. As the total room heat requirement is 74,290 B.t.u., there must be $74,290 \div 22,750 = 3.26$ changes per hour. This means that the total air delivery is $17,891 \times 3.6 = 58,325$ cu. ft. per hour.

All the air brought in, however, must be raised by the furnace from zero to 140 deg., and hence the furnace must provide about twice the amount required to offset heat losses through walls and windows, or 148,580 B.t.u. for heating the air in addition to the 34,522 B.t.u. required for the hot water radiation system, or a total of 183,100 B.t.u. per hour. Assuming 8,000 B.t.u. are utilized from each pound of coal burned, $183,100 \div 8,000 = 22.8$ lb. of coal per hour would be required, with a grate area of 2.8 sq. ft., $22.85 \div 2.8 = 8$ lb. of coal per sq. ft. of grate per hour would be the rate of combustion, not difficult of attainment in the



SECOND FLOOR PLAN OF THE RESIDENCE.

construction and the chimney provided. This is assuming an outdoor temperature of zero, that seldom occurs, and is only of short duration. The coal consumption on Long Island may be calculated closely as follows, assuming that heat will be required 200 days: 200×24=4,800 hr. and 4,800×22.85=109,680 lb. of coal, and 109,680÷2,240=49 tons that would be required if zero temperature prevailed for 200 days, but it has been found from the records of heating plants of different types that one-third of the amount required for 200 zero days, or, in this instance, 16 1/3 tons, should be sufficient. It is regretted that the actual consumption in this plant is not available, as the house is not open during the entire winter.

It has been shown that 3¼ air changes per hour are necessary for heating a portion of the house containing 17,891 cu. ft., or about 58,300 cu. ft. of air per hour would enter the building through the furnace pipes, which have a combined area of 600 sq. in., or 4.16 sq. ft. The volume per second is 58,300÷3,600 =16.19 cu. ft. per second, and 16.19÷4.16 (sq. ft.)=3.89, the average velocity in feet per second, which is practicable. The velocities in the different pipes must vary with the conditions of room size, exposure and ventilation, and size, length, and direction of the pipe. A 10-in. pipe, having an area of 78 sq. in. or 0.54 sq. ft., runs to the parlor, which has 2,100 cu. ft. of space and 142 sq. ft. of E. G. S. The heat loss will be 142×85, or 12,070 B.t.u. To raise the temperature of 2,100 ft. of air 140 deg. requires 2,100×140÷55=5,350 B.t.u.; but, as one-half of the heat is lost by the air escaping by ventilation, 5,350÷2= 2,675 B.t.u. per hour available to offset that loss. The air change to supply the heat is 12,070÷2,675=4.5 air changes. To change 2,100 cu. ft. of air 4.5 times per hour requires the movement of 2,100×4.5, or 9,450 cu. ft. The number of cubic feet of air per second is 9,450÷3,600=2.62 cu. ft. The necessary velocity in the 10-in. pipe, with an area of 0.54 sq. ft. is 2.62÷0.54, or 4.8 ft. per second.

The dining-room has a shorter pipe, with 0.54 sq. ft. area, and contains a space of 2,650 cu. ft. and has an exposure of 111 sq. ft. E. G. S. The heat loss is 111×85=9,435 B.t.u. In a similar way it may be shown that 2.8 air changes per hour are necessary for heating purposes. The corresponding velocity of air in the pipe is 2,650×2.8÷3,600÷0.54=3.8 ft. per second.

An important feature of the equipment is the use of a 10-in. round riser for heating bedrooms B and C on the second floor. By the same method of calculation it is found that a velocity of 5.5 ft. per second will be necessary to bring in enough air at 140 deg. to offset the heat losses. In this round riser is an example worthy of being supported by all engineers, as compared with the flat riser in a partition between studding. It has a larger area, less friction, and a much larger air-carrying capacity than the flat riser. Another good feature is the use of the double baseboard register, which has an opening 8½ x 12 in., into which the 10-in. pipe discharges.

		Contents, cubic feet.	Wall surface, square feet.	Glass surface, square feet.	E. G. S., square feet.	Warm air pipe area, square inches.	Warm air pipe area to space warmed.	Radiation, square feet.
Parlor	15x16-6x8-6	2,100	388	45	142	D-78	1 : 27	....
Living Room	15x15-6x8-6	1,980	166	38	79	B-63	1 : 31	....
Dining Room	16-6x19x8-6	2,650	293	38	111	J-78	1 : 34	....
Toilet	6x8x8-6	404	43	8	19	F*-50	.....	....
Pantry	8x12x8-6	816	90	12	34	G*-50	1 : 16	....
Den	9x9-6x8-6	726	157	13	52	E-50	1 : 14	....
Hall	5x25x17	2,125	136	30	64	A*-63	.....	....
Bed Room A	15x19x8	2,280	373	75	198	....	.....	108
Bath Room A	5x7-6x8	300	28	10	17	....	.....	9
Bed Room B	15x11-6x8	1,380	146	38	74 }	C-78	1 : 42	....
Bed Room C	15x16x8	1,920	218	38	92 }			
Bath Room B	5x8x8	320	51	13	26	A*	.....	....
Bed Room D	10-6x15-6x8	1,302	178	38	82	I-50	1 : 26	....
Bed Room E	10x10-6x8	840	155	13	52	F*	.....	....
Bed Room F	9x14x8	1,008	59	13	28	H-50	.....	....
Bath Room C	5x8x8	320	28	12	19	G*	.....	....
Servants' Chamber A	8x14x8	896	159	25	72	....	.....	42
Servants' Chamber B	7-6x11-6x8	690	135	25	57	....	.....	36
Totals		22,057			1,218	600		195

* Pipe supplies two registers.

The air supply to the furnace is taken from the north, the source of prevailing winds, and is through a duct 13 x 36 in. in size, having an area of 468 sq. in. The statement was made that the system would provide a superabundance of fresh warm air. It is well to point out that the heat losses, as figured by the total E. G. S., amount to 103,020 B.t.u. per hour, and that 79,592 B.t.u. per hour are lost from the air changes or the ventilation that attended the use of an indirect system of heating. If the estimated 16 tons of coal are required for heating this home it is clear that probably 6 tons are required for the ventilation.

Little has been said about the piping for warm air or hot water, as the plans and table will give information which the student may desire. Both systems of piping have a gradual pitch and are insulated with air-cell covering. Bright tin is used in

the furnace pipe. The expansion tank for the water system is in the servants' chamber B.

DISCUSSION.

Mr. Lewis: I would like to suggest just two thoughts along the line of combination heating, not to lose sight of the consideration that almost always, in proportioning the radiation, that is, the part which is supplied from the steam or water heater in the furnace is not often sufficient to heat the room. Quite often the mistake is made in cases of that kind of expecting too much from the boiler capacity, not considering that each square foot of radiation will give off more heat than it would in the ordinary direct steam-heating, where the radiation is sufficient to heat the room.

The other thought is, you know that on a wagon with a pair of doubletrees they often use some eveners to which to hitch the pair of horses. The object is to let the pull be equalized. When the air part of a combination system is not quite sufficient, it seems better to put in above the furnace an indirect radiator connected with the circulating system. Then if the air does not get warm enough from the furnace the radiator helps equalize the results.

Mr. Williams: I was called on last year to pass on the heating of two school buildings on which there was a dispute, and these schools were heated by combination heaters. Whether purposely or not, they had no established rating of the furnace or of the heater in the fire pot. As I was listening to this paper and the discussion it recalled the trials of last summer to my mind again. One of the most difficult of undertakings is to rate a furnace with the present data, for there seems to be no reliable data of the transmission of heat from the fire to where it is needed. But one of the most difficult things I had to contend with in the rating of these furnaces was just what that little hot water boiler would do, and I came to the conclusion that the makers of such combinations knew but little on the subject.

In asking questions about these plants I found that on the average they had to fill that little boiler seven or eight times a day, and the colder the weather the more times they had to fill it. Being right in contact with such intense heat the water was so rapidly turned into steam, and the result was it escaped through

the relief pipe to the roof. One couldn't measure how much water was used. It is pretty difficult, also, to make a rating of the value of radiation attached to a boiler in the fire pot of a furnace.

Mr. Davis: I note Mr. Chew gives the transmission of the heat of the water in the auxiliary heater there as 6,276 B. t. u. per square foot. While I never had an opportunity to check up a combination heating system, I have checked up in a number of cases where an auxiliary coil was introduced into the combustion chamber around the fire pot for heating water for domestic purposes. After probably twenty-five or thirty experiments, checking the amount of pipe, my experience was that the transmission was somewhat higher than that, that it gave uniformly a transmission approximating 10,000 B. t. u. per square foot of pipe surface in the combustion chamber, in the fire pot. The method I usually adopted was to have about one-third of the pipe coil in the fire and the remainder of it, from one-fourth to one-third, in the combustion chamber. Now whether that would materially change the rate of transmission, I am not sure. I think it would when the fire was burning brightly. The transmission in some cases ran higher, but the average was about 10,000 B. t. u. under those conditions.

Chairman Hale: I would like to ask Mr. Chew if this was so successful that they have thought of adopting this same system in other places. I would like to know from Mr. Chew how long that has been in operation, and whether he knows that the house was comfortable during the season, that is, whether the hot water and the hot air worked together as uniformly as desired or satisfactorily.

Mr. Donnelly: I am very much interested in having these figures of transmission put upon the record, because I think they are helpful. I was interested in Mr. Davis' figures of transmission. Some years ago I put in quite a number of hot water combination heating apparatus. They used to set in the fire pot, where practically all the surface was below the line of the fire. The surface was figured from rule of thumb at that time, but about a square foot of radiation to two square inches of exposed surface in the fire pot, in direct contact with the fire. That would give a transmission of 18,000 B. t. u. per square foot, figuring the radiators at 250 degrees. The radiators frequently got that high. It was sometimes very difficult in very cold weather to keep the

radiation below the boiling point. I really believe that in this house the conditions would be improved by placing a large radiator almost immediately above the surface. This radiator might be shut off in some conditions of weather, and turned on in order to keep the water part of the apparatus from boiling. It is, you see, impossible to regulate the draught to get more hot air while getting less hot water, or *vice versa*. This difficulty resulted in the taking out of many combination steam furnaces. I have known places where the lack of warm air was so apparent, especially in the morning, that they have tied the safety valve down, disconnected the damper regulator, which merely threw enough pressure in the steam apparatus to blow it up. The same thing happened in the case spoken of by Mr. Williams.

John S. Makin: I can hardly keep my seat when I hear talk like this on the floor. It carries me back about twenty-five years when I first started experimenting with combination heating. To-day I do not believe I could get anybody that would dare put in one. I would like to see one work the way they say it works. I doubt whether the water would circulate. I really would not know which way the water would circulate in that kind of a heater. I do not think you would put in a boiler with a return pipe over the hottest part of the fire. I think it would take something more than an engineer to calculate what it would produce and what its results would be under various conditions.

A. G. Cripps: About twenty years ago I installed a combination warm-air and hot-water heating system in a building in Iowa City, in which there were 1,200 square feet of direct hot-water radiation used in different rooms and the hot water was furnished from a water heater installed in the fire and combustion chamber of a 52-in. furnace.

Abram C. Mott: The hot-water attachment mentioned by Mr. Cripps is a hollow casting resting on the fire pot of the furnace, with five arms extending to a cone in the center, which makes it practically suspended over the fire. This heater exposes 7 square feet of direct heating surface and 11 square feet of indirect heating surface, and we have found that it is necessary to use not less than 700 square feet of direct hot-water surface properly proportioned to balance the capacity of the warm air heated by this size of furnace. I know of no rule, nor do I think it is possible to have any fixed rule for the proportionment of

warm air and hot water capacity of this or any other combination furnace which will apply in all cases. In the installation of each such furnace, it must be considered that each individual job must have a furnace fitted to it, just the same as a coat must be fitted to the individual man. In my own residence I installed the first combination furnace that we made. The work was carefully done, and we felt that we had struck the proper proportion the first time. This worked absolutely satisfactorily until January weather, then the house could not be heated. If attempt was made to push the fire to heat with hot air, the water boiled in the system, while the portion of the house heated by water was all right, that portion heated by hot air was decidedly unsatisfactory. For a remedy we placed an 8 foot radiator in the hall which had previously been heated with hot air. We also left openings in the pipe to attach another radiator should it be found necessary. It was found that, with this additional 8 foot radiator in the hall, we could fire the furnace and get a sufficient amount of hot air and a sufficient amount of hot water in the coldest weather. Provision is now available by means of which the hall can be heated with either hot air or hot water, and it became the balancing room of the system. In cold weather it is heated with hot water and the hot air is shut off. In warm weather it is heated with hot air and the hot water is shut off. It is my belief that in all cases on combination heating it is necessary to have at least one good-sized room or hall which can be heated either way to balance the job. Another difficulty encountered was in the firing. The difference of at least 30 per cent. would be made in the hot-water capacity of the furnace by carrying either a low or a high fire. To illustrate, if the fire pot was about two-thirds full of live coal, it would take care of 400 feet of radiation; but, if the fire pot was carried full of live coal, it would carry 600 feet of radiation. The result of years of experience was that each individual job required so much experience and engineering ability on the part of the man who installed the heating system, that there was never any certainty as to whether the user would be satisfied or not with the result and some years since we gave up the manufacture of this style of furnace and discouraged its use.

George V. Greey: A large combination heater is used in warming our salesroom and office, and for the past two years there has been no additional water put in it. Water in a combi-

nation heating system will not boil if the radiation placed in the various rooms is made on a little more generous apportionment than is ordinarily followed in the installation of a hot-water heating plant. This is a point that should not be overlooked. More surface may mean a lower temperature for the water, but it also prevents overheating when the furnace is fired hard in cold weather to heat the air entering at a very much lower temperature to the desired temperature for the effective service at the outlet.

Mr. Chew: At the beginning of the paper a paragraph reads: "The apparatus has been subjected to the test of actual use, and the bill has been paid, so there is the usual evidence that the judgment of the engineer was correct and the service satisfactory." I gave further testimony of that when I spoke of the architect, because I know when one is well satisfied it is good evidence that he has been to see the job. I know that his client is pleased with it, and that he recommends its use to others.

I think on the discussion of water circulating backward or otherwise it is immaterial so long as it circulates. In the case of a coil in the fire pot, where the pipe is lying in the fire, the transmission will be very high. I wrote Professor Shealy, of the University of Wisconsin, and called his attention to a feature of the case on which nobody as yet has spoken; that is, the effect this heater would have on the combustion of the fuel. I have assumed that a water heater so small in diameter, filled with hot water, would have less effect on combustion than would the outer air coming into contact with the outside of the fire pot. In reference to fuels that burn with a short flame, Professor Shealy says he thinks any particle of combustible matter, whether it is of a gaseous nature or some solid form, will have as complete combustion as it will ever have over the fire when it gets six inches away; and consequently I believe that this water heater has little or no effect on the combustion, so far as the air-heating surfaces of the furnace are concerned.

A certain amount of water-heating surface can be inserted over a fire without any effect whatever on the coal pile, so far as heating all parts of the house is concerned, and with a hot-water heater used in this way one or two rooms can be warmed at no extra expense. Certainly one room can be warmed without affecting the coal pile; and it is the coal pile that is the final test of the

correctness of such a plant. If a man burns eight tons of coal this year, and puts in a water heater and heats another room next year and still burns only eight tons, it means that there has been an economy effected. Now, bearing out that idea again, Professor Shealy says: "I recently designed a system of heating for a friend here. His furnace was amply large, but four very badly exposed rooms would not heat, so he added a heater to the fire pot and 220 square feet of hot-water radiation to supplement the warm air. The system is working perfectly, and I do not think that the difference in the fuel consumption will be increased."

I have another letter from a man who was very successful around Boston in erecting this class of work. He says it requires more care and study to lay out a successful combination system than either hot-water or hot-air systems. But it is more expensive, and that fact keeps it out of the cheap competition class. He further says something which may be questioned: "A house which is heated by indirect steam on the first floor and direct radiation on the second floor can be heated with a combination hot-air and water system, with about one-third less coal, and the installation cost would be reduced about the same proportion. A combination system also costs less to keep in repair."

I have still another New England letter, but I will not take more time, as I have given the gist of their ideas for the Society to put in the proceedings. Mr. Lewis, in giving the information he has, and Mr. Davis, giving what he has, and Mr. Donnelly, what he has, is to my mind the ideal method of conducting meetings. We are here to give information, and the man who writes a paper is not put under fire to be cross-questioned. The member who writes a paper puts a duty upon the other members to furnish their information to supplement that which he gives in the paper, to corroborate it, and to supply any deficiencies, or to correct any errors in it that may develop. I thank those that have participated in the discussion for the part they have taken therein.

CCCVIII.

REPORT OF THE COMMITTEE ON SCHOOLROOM VENTILATION.

Next to efficient teaching the most important requirement for successful school work is properly heated and ventilated schoolrooms.

STANDARDS.

Although it is futile to attempt to set identical standards of efficiency for the heating and ventilating of schoolrooms, it is true that the possibility of finding new efficiency factors is not remote.

It has been explained often enough that the best temperature is still to be found, and that it is absolutely out of the question to measure in definite terms the difference that makes a certain day one in which work goes on with vim and vigor and another day one in which everybody desires the end to come, and that right speedily.

The results reached by the systems for air conditioning should be measured on a standard based on health of pupils, and not on dollars of cost of installation.

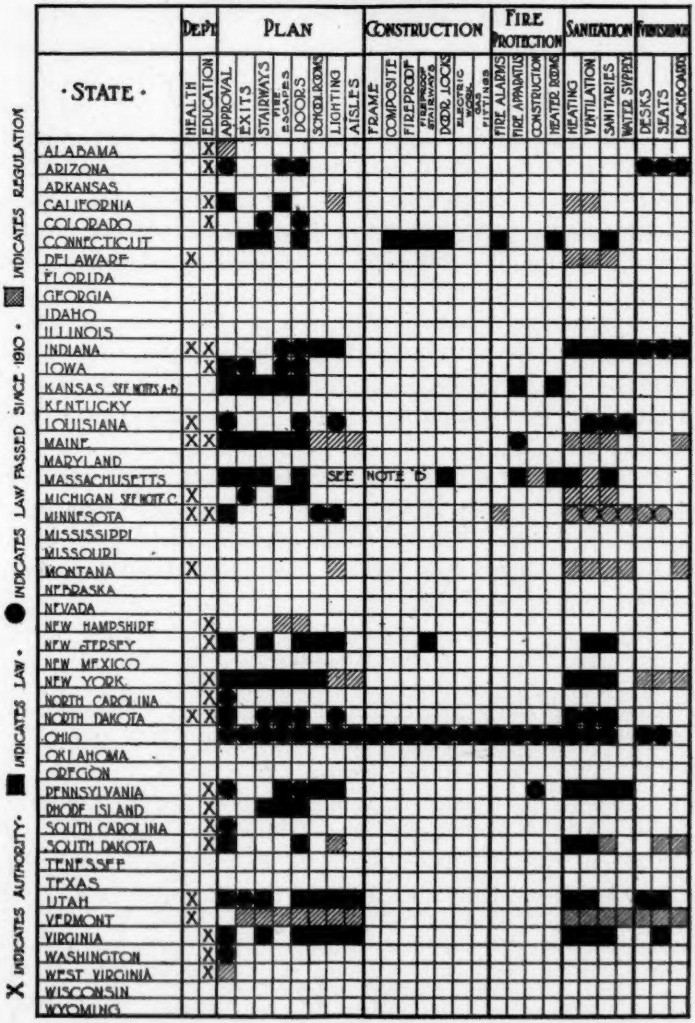
PRESENT CONDITIONS.

The pupils in open-air schools seem to be in better health and to progress faster than the pupils in our best buildings having modern systems of ventilation. That anyone knowing this fact should be responsible for the erection of buildings having no proper ventilating systems is truly criminal.

The most perfect construction yet reached is that in which the building has facilities for open-air conditions and also has a complete system for air conditioning to be used when weather conditions make it unwise to follow the open-air method.

CHART SHOWING STATUS OF REGULATION OF SCHOOLHOUSE CONSTRUCTION IN THE UNITED STATES IN 1912.

COMPILED BY FRANK IRVING COOPER, BOSTON



NOTE A THE PLANS FOR SCHOOL BUILDINGS IN THIS STATE MUST BE APPROVED BY STATE ARCHITECT

NOTE B THESE RULES ARE PREPARED BY DEPARTMENT OF INSPECTION OF WORKSHOPS, FACTORIES AND PUBLIC BUILDINGS

NOTE C THESE LAWS AND REGULATIONS APPLY TO STATE BUILDINGS ONLY

FINDINGS OF THE RUSSELL SAGE FOUNDATION.

The Russell Sage Foundation has just completed a comparative study of the public school systems in the forty-eight states and what they found is astonishing. The report states that Massachusetts spends more money on school buildings per child than any other state in the Union, the average equipment per pupil being $115.00; New York, with $111.00, is a close second; Mississippi stands at the foot, spending only $4.00 per pupil. There are some climatic reasons for this difference, but there seems no good reason for the kind of buildings this low expenditure indicates.

A reference to the chart at the end of this report will show that Massachusetts stands second among the states in the completeness of its regulations for proper supervision of the erection of school buildings, while Mississippi has no state control over its buildings.

That the low grade of building and equipment has its influence on school life is further shown by the Russell Sage Foundation in the rank of the states based on the pupils' attendance at school, Massachusetts in this class ranking second and Mississippi again standing at the foot.

PUBLIC INTEREST.

These comparative studies are of interest to us when we consider the awakened public interest in proper air conditioning plants. Two towns situated geographically at the extremes of Massachusetts have made contracts this past summer for ventilation which should include humidifying the air in their new high school buildings, and the city of Boston has decided that all new buildings shall be so arranged that they may have open-air schoolrooms.

THE BOSTON EXPERIMENT.

Those teachers that know of the air conditioning in the Oliver Wendell Holmes school building are asking that some method of air moistening shall be introduced in the heating systems in their buildings.

The work of this committee, the experiments which have been conducted, and the interest which has been aroused have had undoubtedly great influence in bringing about the present high standard taken by the school committee of the city of Boston in regard to heating and ventilating of new school buildings.

REPORT OF THE AMERICAN SCHOOL HYGIENE ASSOCIATION.

The committee of the American School Hygiene Association on heating and ventilating school buildings says in its report: "Open windows did not always make conditions satisfactory. When there was no breeze, ventilation was inadequate. When the window was near the street, noise and dust were introduced. Open windows were productive of uneven temperature. Persons near the windows would be too cold, exposed to strong and sudden drafts; those away from the windows would frequently be too warm and in relatively motionless air.

"Regulating temperature by having the teacher open windows gave her one thing more to attend to. The teacher would forget or the temperature of the room would be kept at a point which was most pleasant to her. It seemed, therefore, obvious, first, that the air should be forced into the room in regular quantities in such a way as not to depend upon or demand the thought of the teacher; second, the air should be free from dust; third, the air should be taken from odorless sources; fourth, the air should be introduced into the room in such a way as to change the contents several times an hour without making perceptible drafts; fifth, the temperature of the room should be automatically regulated.

"The conditions just named with reference to the nature and excellence of the air have been provided by the heating and ventilating engineers.

"In many instances heating and ventilating plants are not competently managed and the lack of best results may, in these cases, be attributed to the fault of the administration rather than to the fault of the system.

"Heating and ventilating systems have not as yet been able to make indoors as healthful as outdoors—no matter what the system or how managed. This has raised a serious question in the mind of your committee as to whether existing standards

are adequate, for, as has already been stated, even when the standards are fully met, the differences between the beneficial quality of indoor and outdoor air do not seem to have disappeared.

"The chief question does not seem to be a question of engineering; the best modern systems of ventilation do seem to do what has been asked of them."

CONCLUSION.

Your committee has found that there is no agreement among the physiologists and the medical profession as to what constitutes best conditions of temperature, humidity, and air movement.

When they agree upon the conditions to be reached and communicate their agreement to the heating and ventilating engineers a great step will have been taken, for with the fixing of a standard of the requirements the chief difficulty will disappear.

Respectfully submitted,

FRANK IRVING COOPER, *Chairman.*

CCCIX.

EXPERIMENTS ON HUMIDIFYING AIR AT THE OLIVER WENDELL HOLMES SCHOOL.

CHARLES F. EVELETH.

It is only within very recent times that any serious attention has been paid, either by physicians or by heating and ventilating engineers, to the effect which the relative humidity has upon the comfort and health of people who by force of circumstances are compelled to daily gather together in large numbers in such places as factories, mills, schools, colleges and the like. Very little direct evidence has ever been published either, to prove or disprove the value of humidification, and those who have spoken in favor of it have argued from an academic standpoint, rather than in the light of any specific data.

The Schoolhouse Commissioners of the City of Boston, acting with the School Committee, set aside an appropriation which enabled the writer, in conjunction with Dr. Thomas W. Harrington, to purchase apparatus and carry on a series of experiments covering a period of about three months, for the purpose of obtaining definite information upon the subject.

Briefly stated, the objects of the experiment were as follows:

1st. To find whether the mental and physical conditions of the occupants of a school are improved by increasing the relative humidity of the air in the rooms.

2d. To determine at what point the relative humidity should be maintained, to insure the greatest degree of comfort.

3d. To find how much lower the temperature may be comfortably maintained when the relative humidity is increased.

4th. To obtain a record of the humidity of a school building during the winter months when heated and ventilated in the ordinary manner, by means of a plenum system.

5th. To see whether it is practicable to moisten the air by

means of a steam jet and keep the humidity within reasonable control.

In order to make a comparative study of the effect of increased humidity upon the physical and mental conditions, observations should be made upon children who live and move in the same walks of life, attend the same school and occupy similar grades.

The Oliver Wendell Holmes School was selected as being the best adapted for the purpose of conducting the tests. It contains 24 class rooms, beside a manual training room and cooking room. On the basis of 40 pupils per classroom it has a capacity of nearly 1,000 children. The building is of brick, three stories in height, of the so-called fireproof construction throughout. The floors and stairs are of reinforced concrete, all of the principal rooms having upper floors of hard wood laid on screeds. The partitions are built of terra cotta blocks and plastered. It contains a plenum system of heating and ventilation, the air supply to each half of the building being furnished by a steel plate fan. The classes are so arranged that corresponding grades of pupils occupy similar rooms in each half of the building.

The second floor plan (Fig. 1) shows very clearly the shape of the building, the arrangement of the rooms and the exposure. The third floor is similar, the assembly hall being two stories high. The space on the first floor corresponding to the hall is divided into classrooms.

The arrangement of the heating and ventilating apparatus is outlined in the basement plan. (Fig. 2.) Steam is supplied by two horizontal return tubular boilers to a low pressure steam engine, which is belt-connected to two single-inlet, 7-foot, steel plate fans, each furnishing air to one-half of the building. The engine exhaust is turned into the heating system and this is supplemented by live steam passing through a reducing pressure valve. The water of condensation is returned to the boilers by an automatic pump and receiver. The classrooms and the assembly hall are heated and ventilated by warm air. Only the small administration rooms and corridors contain direct radiators. Fresh air is taken into the system through a hooded intake at the center of the building and is warmed by a primary heater of cast iron indirect pin radiators. The temperature is maintained at a uniform point, varying from 60 to 70 degrees

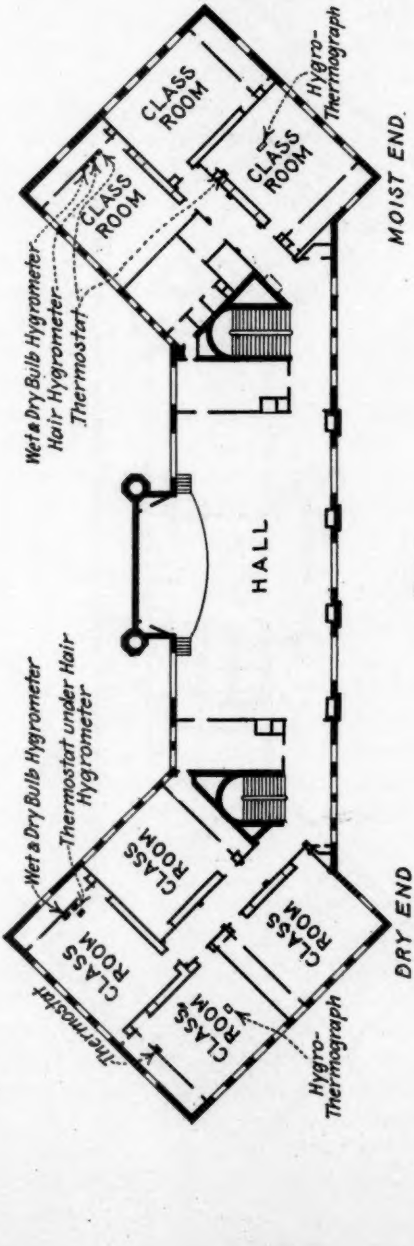

CLASS ROOM
CLASS ROOM
CLASS ROOM
Hygro-Thermograph
MOIST END
Wet & Dry Bulb Hygrometer
Hair Hygrometer
Thermostat
HALL
Wet & Dry Bulb Hygrometer
Thermostat under Hair Hygrometer
CLASS ROOM
CLASS ROOM
CLASS ROOM
CLASS ROOM
Thermostat
Hygro-Thermograph
DRY END

FIG. 1.

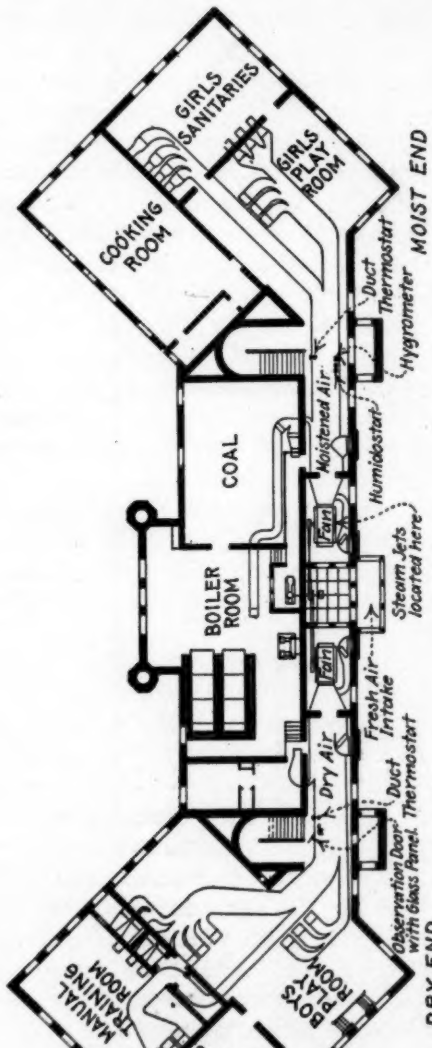

GIRLS SANITARIES
GIRLS PLAY ROOM
COOKING ROOM
COAL
BOILER ROOM
MANUAL TRAINING ROOM
BOYS SANITARIES
BOYS PLAY ROOM
Moistened Air
Dry Air
Fan
Fan
Duct Thermostat
Hygrometer
Humidostat
Steam Jets located here
Fresh Air Intake
Duct Thermostat
Observation Door with Glass Panel
MOIST END
DRY END

FIG. 2.

Fahrenheit, as the occasion demands, by mixing dampers operated by graduated action thermostats, one being placed in the air beyond the discharge from each fan, as shown on the drawing. The air is conducted through galvanized iron ducts on the basement ceiling to the foot of the risers leading to the individual classrooms, where it is further heated to a temperature of 95 degrees Fahrenheit, by supplementary stacks of indirect radiators, each under the control of a thermostat placed in the room.

The arrangement of mixing dampers and duct thermostat, and the location of the supplementary heater and room thermostat, are shown somewhat in detail on the sketch of humidifying apparatus. (Fig. 3.) The warm air enters each classroom through an opening about 8 feet above the floor, and the foul air is withdrawn by gravity through a vent outlet at the floor, both being situated along the same wall. These are shown on the second floor plan. (See Fig. 1.)

Before beginning the experiments, all the dampers and deflectors were so adjusted as to furnish an air supply to each room on the basis of 30 cubic feet per minute per occupant.

The relative humidity of the air supply to the north end of the building was raised by introducing moisture in the form of steam, while that of the south end remained in its natural state. Readings were taken of the humidity and temperature of the air in the duct and of the classrooms of each half of the building. The children of similar grades on the moist and dry side were subjected to similar mental tests, and a record was kept of both the physical condition and the percentage of attendance.

Owing to lack of space an air washer could not be installed in connection with the existing apparatus, without making too many structural changes, and the steam jet was found to be the only moistening device which could be economically applied. The accompanying sketch (Fig. 3) shows the essential details. Six 1¼-inch pipes spaced an equal distance apart, were suspended in front of the inlet of one of the fans. A single row of holes, 1/16 inch in diameter and 1 inch apart, were drilled in each of the two outer pipes, the others having two rows similarly placed. The pipes were connected up in two groups in such a way as to equalize the flow of steam as nearly as possible. The supply pipe was connected to the main steam drum, taking steam at boiler pressure. This was partially throttled by a valve near the boilers,

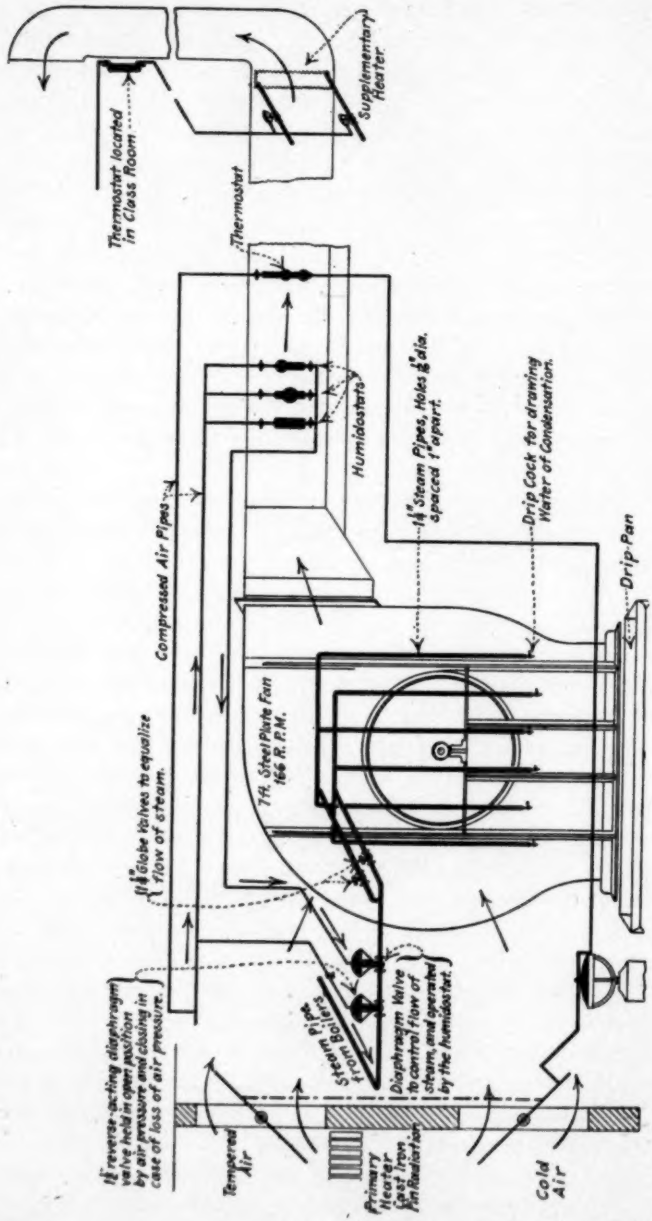

Thermostat located in Class Room
Supplementary Heater
Thermostat
Humidostats
Compressed Air Pipes
1¼" Steam Pipes, Holes 1/8" dia. spaced 1" apart.
Drip Cock for drawing Water of Condensation.
Drip-Pan
7 ft. Steel Plate Fan 166 R.P.M.
1¼" Globe Valves to equalize flow of steam.
1¼" reverse-acting diaphragm valve held in open position by air pressure and closing in case of loss of air pressure.
Steam Pipes from Boilers
Diaphragm Valve to control flow of steam, and operated by the humidostat.
Tempered Air
Primary Heater Cast Iron Pin Radiation
Cold Air

FIG. 3.

further reduction being made, as the occasion required, by the globe valve in the branch supply to each group of perforated pipes. The volume of steam issuing from the openings was regulated by a diaphragm valve operated by compressed air taken from the automatic temperature control system and controlled by a humidistat placed in the main warm air duct. The exact location is shown on the basement plan. In order to prevent flooding of steam in case of failure of the air pressure, a reverse acting diaphragm valve was also installed. This valve was normally closed by means of a spring and opened when the proper air pressure was maintained on the system. A three-way cock placed in the air piping to the diaphragm top of the valve permitted its operation by hand. The apparatus could thus be easily started and stopped by manipulating the cock. The water of condensation, which always formed when the apparatus was first turned on and which would slowly collect during use, was drawn off through a lever handle air-cock at the bottom of each pipe and caught in the drip pan underneath.

Humidistats of three different makes were connected up to the air-piping, shut-off cocks being installed to cut out any two of them as desired. The action of the instrument is somewhat similar to the thermostat, and depends upon the change in shape of a piece of cross-grained hardwood, due to presence or absence of moisture. Two of them had a graduated action, causing the control valve to slowly turn on or off the steam. The other was of the positive type, and its effect upon the movement of the valve disc was very much like that of a positive thermostat upon a set of mixing dampers, *viz.*, either completely open or closed, there being no midway position. There was either a full flow of steam or none, and the results were far from satisfactory. One of the other instruments, having a graduated action, gave excellent satisfaction, the curtain of vapor in front of the fan inlet being very uniform and changing gradually with the varying demand for moisture.

The method of adjusting the apparatus was as follows: The duct thermostat controlling the mixing dampers was set to keep the tempered air in the duct at approximately that desired in the classrooms, *viz.*, a dry bulb temperature of from 63 to 67 degrees F., and extreme care was used to regulate it closely. The humidistat was then adjusted to maintain the desired rela-

tive humidity at this temperature. The temperature of the classroom and of the air in the duct, where the control apparatus was located, being the same, the relative humidity of the room would correspond to that in the duct. The supplementary heater had no influence upon the quantity of moisture introduced, as it was beyond this point.

When starting up in the morning, it was found necessary to turn on the steam jet gradually, as the instrument would not at once assume proper control of the jet. If this was not done the rooms became very uncomfortable on account of excessive moisture.

Before beginning the experiments the water was drawn off completely from both the boilers, the piping was thoroughly blown off, and fresh water introduced to prevent as far as possible any odor due to oil or foreign matter. Notwithstanding this, a slight odor, somewhat objectionable, was noticeable, on first entering the classroom, when the relative humidity was over 55 per cent.

In the basement fresh-air duct on each side of the building there were placed wet and dry bulb thermometers, of a pattern similar to those in use by the Weather Bureau of the United States Government, and also a hair hygrometer. A tight-fitting glass door of ample size permitted the instruments to be read from the outside of each duct, eliminating as far as possible any exterior influences. Observations were taken each morning about 10 o'clock, after the apparatus had assumed normal working conditions. The hair hygrometer was set daily to correspond to the readings obtained from the wet and dry bulb thermometers. This instrument was installed particularly for use by the janitor, as it indicated directly the humidity in per cent., and enabled him to determine whether the apparatus was working properly.

In rooms 12 and 17, on the second floor, located respectively on the dry and moist ends, were placed recording hygrothermographs, from which complete autographic records were obtained of the temperature and relative humidity, the charts being replaced weekly. Each instrument was securely mounted upon a wooden shelf fastened to a standard which was screwed to the floor and guyed with wires and turnbuckles to prevent vibration. It was necessary to place it about six and one-half feet above

the floor to prevent interference by the pupils, and care was taken to locate it in such a position as not to be affected by the incoming fresh air. The rooms were alike in respect to outside wall and glass area, and as they had no direct sunlight during the day, it was not necessary to take into account the effect of the sun's rays, upon the readings.

On the third floor in rooms 20 and 22, wet and dry bulb thermometers were placed similar to those described above. They were located on an inside wall, near the inner corner of the room, and at about the height of the hygrothermographs.

The test was started on January 3, 1912, and terminated on March 28. As stated above, readings of the various instruments of the fan speed and steam pressure were taken, each morning, generally about 10:30, after the humidifying apparatus had assumed its normal working condition. The readings of the hygrothermographs were checked up by a sling psychrometer and a standard thermometer, and the instruments readjusted if necessary. The classrooms were warmed and ventilated by the fan system alone, no outside ventilation by opening the windows being permitted.

The average results for the months of January, February and March are given below. Those of the outdoor humidity were obtained from the United States Weather Bureau in this city, and taken at 8:00 A. M. daily.

AVERAGE READINGS FOR JANUARY, FEBRUARY AND MARCH, 1912.

Temperature and Humidity in Fresh Air Duct.

	Moist End			Dry End		
	Dry Bulb	Wet Bulb	Relative Humidity	Dry Bulb	Wet Bulb	Relative Humidity
January	68.2°F.	56.1°F.	46.0%	67.7°F.	49.1°F.	21.2%
February	66.1°F.	54.1°F.	44.3%	67.5°F.	49.9°F.	24.4%
March	65.1°F.	55.2°F.	52.6%	66.3°F.	52.8°F.	34.8%

Temperature and Humidity in Classrooms 12 and 17 from Hygrothermographic Charts.

	Room 17—Moist End		Room 12—Dry End	
	Temperature	Relative Humidity	Temperature	Relative Humidity
January	66.2°F.	50.1%	69.4°F.	34.3%
February	65.0°F.	41.2%	68.4°F.	23.6%
March	65.1°F.	47.3%	68.1°F.	32.2%

Temperature and Humidity in Classrooms 20 and 22.

	Room 22—Moist End			Room 20—Dry End		
	Dry Bulb	Wet Bulb	Relative Humidity	Dry Bulb	Wet Bulb	Relative Humidity
January	67.4°F.	57.2°F.	53.4%	69.5°F.	54.1°F.	34.4%
February	68.5°F.	56.5°F.	47.1%	68.2°F.	53.4°F.	35.8%
March	67.6°F.	57.8°F.	52.6%	67.8°F.	55.4°F.	44.3%

Outdoor Humidity.

	Day Reading—8 A.M.	Night Reading—8 P.M.
January	71.3%	63.5%
February	64.8%	55.7%
March	70.7%	63.5%

We have reproduced two larger scale charts taken from the hygrothermographs in corresponding rooms on the moist and dry ends of the building for the week of February 5 to February 12, 1912, which represent the events taking place within the rooms during this period. For the purpose of comparison we have plotted the hourly readings of the outdoor temperature, and also the outdoor relative humidity from daily observations made at 8:00 A. M. and 8:00 P. M., both taken from the weather bureau records. The charts (Fig. 4) bring out very clearly the intimate relationship between temperature and humidity, and it is perfectly evident that no system of air-moistening will prove successful unless both the temperature and the humidity are under close and accurate control.

The chart of boiler pressures (Fig. 5), taken from the recording steam gage, and covering the same period, is perhaps typical of the lack of care taken by some janitors in operating their boilers. Such a variation in steam pressure must necessarily affect the speed of the engine and the resulting air delivery to the rooms.

The diagram of indoor and outdoor relative humidities is not strictly accurate, the outdoor readings being taken at 8:00 A. M., while the others were made about two and one-half hours later. It is submitted to show the wide variation taking place out of doors and to bring out graphically the additional moisture introduced into the rooms on the wet side.

The average results of the experiments may be summed up as follows:

(A) With the outside temperature ranging from 0 degrees to 10 degrees above, precipitation was observed on the windows in the moist end of the building when the humidity was 40 per cent. and over. The teachers were inclined at the outset to raise some objections, but became accustomed to the conditions after a short time.

(B) In the rooms on the north end of the building it was quite apparent that there was less body odor, so-called, than on the dry end.

(C) An increase in temperature of from four to five degrees was far more apparent on the moist side than on the dry.

(D) Complaint was raised when the apparatus was first turned on each morning, of a very close and oppressive feeling

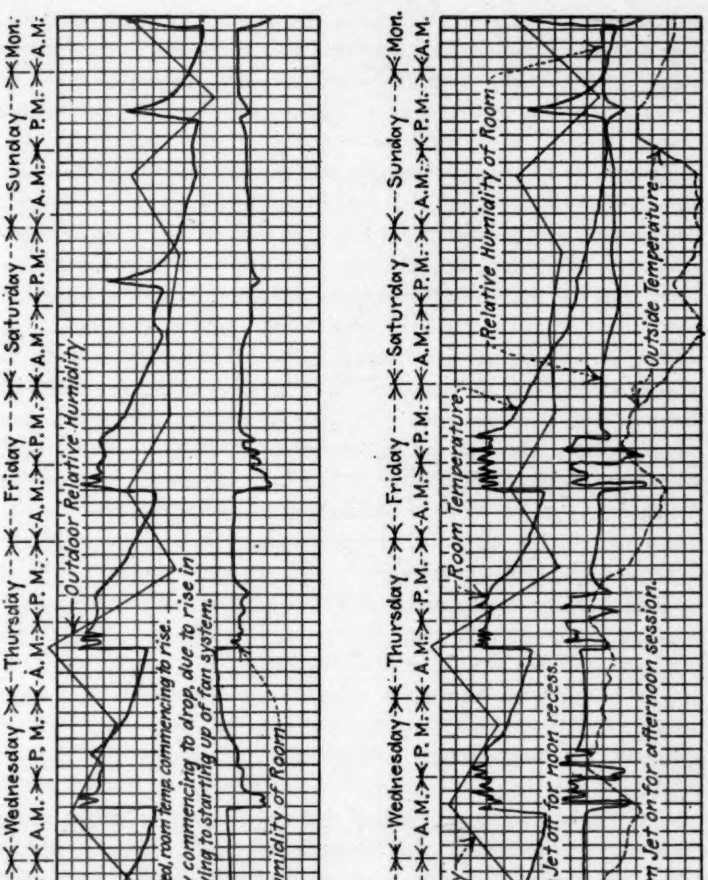

Monday Tuesday Wednesday Thursday Friday Saturday Sunday Mon.
A.M. P.M. A.M. P.M. A.M. P.M. A.M. P.M. A.M. P.M. A.M. P.M. A.M. P.M. A.M.
80 70 60 50 40 30 20 10 0
Temperature
Outdoor Relative Humidity
Fan started, room temp. commencing to rise.
Humidity commencing to drop, due to rise in temp. owing to starting up of fan system.
Relative Humidity of Room
Outdoor Relative Humidity
Room Temperature
Relative Humidity of Room
Outside Temperature
Steam Jet off for noon recess.
Steam Jet on for afternoon session.
Steam Jet turned on

FIG. 4.

in the rooms, and also an objectionable odor. Upon investigation it was found that the humidostat did not at once act upon the control device, and too much steam was introduced into the air, thereby raising the humidity far above the proper point. By checking the flow at the beginning this was almost entirely overcome.

Originally the room thermostats were mounted directly upon the slate blackboard, causing a decided overheating of the rooms Monday mornings, due to influence of cold walls upon the thermostats. This trouble was overcome to a certain extent by mounting the thermostats upon wood backs, thus insulating the metal from the blackboard. The cause for a cold building on Monday morning is very clearly shown if a moment's study is given to the reproduction of the hygrothermograph chart and the plot of boiler pressures. The latter indicates that steam was kept up only about eight and one-half hours each school day, none on Saturday and a little on Sunday afternoon. During the seven days practically three-quarters of the time no pressure was registered on the gage. The curved lines of drop in temperature at night are very similar for the several periods of school session. On Saturday night, however, with the outside temperature hovering around zero, the room dropped below freezing, remaining so for a long period of time.

On Sunday afternoon the apparatus was started up with a corresponding rise in temperature, and the quick recovery on Monday morning showed that a sufficient amount of radiation had been provided to bring up the temperature of the air in the room. It is, of course, evident that a greater time must elapse before the walls, floors, ceilings and furniture become heated to the same degree. The teachers and pupils of this particular school have complained repeatedly of the discomfort arising from the cold floors and furniture on Monday. The remedy is to be found in disciplining the janitor, and there was a marked improvement each morning when the autographic evidence was submitted to the proper authorities. The moral effects of a recording pressure gage and a recording thermometer are invaluable in maintaining proper operation of heating plants.

(E) While the heating apparatus in the average school may perhaps be operated a greater number of hours in the week than the one under discussion, nevertheless an ample factor of safety

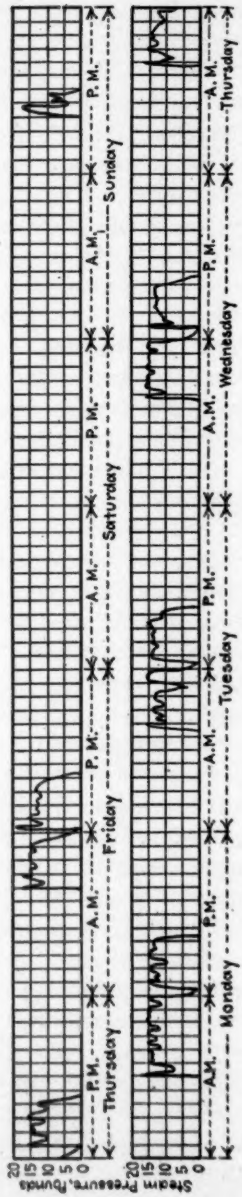

Steam Pressure, Pounds
20 15 10 5 0
20 15 10 5 0
P.M. Thursday
A.M. P.M. Friday
A.M. P.M. Saturday
A.M. P.M. Sunday
A.M. P.M. Monday
A.M. P.M. Tuesday
A.M. P.M. Wednesday
A.M. Thursday

FIG. 5.

ought always to be used in figuring radiating surface to allow for quick heating in the morning.

The results obtained when humidifying the air by means of a steam jet lead us to the following conclusions:

1st. To secure the greatest comfort, the relative humidity should not exceed 55 per cent.; somewhere between 45 and 50 per cent. is probably the best range.

2d. With the humidity at 55 per cent. the temperature of the room should never rise above 65 degrees Fahrenheit. A temperature of from 61 degrees to 62 degrees will give better results.

3d. Moistening the air up to 40 per cent. or above should never be attempted unless both the heating system and the humidifying apparatus can be kept under close control. With a room temperature of from 70 to 75 degrees, and a relative humidity of 50 per cent., there is a very pronounced feeling of oppression and physical discomfort, as well as a perceptible odor which is disagreeable.

If the heating apparatus does not have automatic temperature control, the regulation being in the hands of the teacher or janitor, there will be many times when it will rise above 70 degrees. Under such conditions it is not wise to increase the humidity of the air much over 35 per cent., and we should be inclined to omit it altogether.

No system of air-moistening will prove successful unless both the temperature and the humidity are under close and accurate control. A jet of steam blown into the incoming air without some form of close regulation, is at best a very crude affair. While the introduction of steam in moderate quantities may seem to the average layman to meet all of the requirements, it is of doubtful value, and when delivered in large amounts is liable to produce great discomfort.

Dr. Harrington submitted the following reports of the effect of increased humidity upon the mental and physical conditions of the pupils:

1st. On the basis of similar mental tests conducted upon pupils occupying similar grades on both the moist and dry sides of the building no appreciable difference was found.

2d. The three rooms on the moist side had a percentage of attendance of 100. The percentage of attendance of all teachers

on the moist side was 100; on the dry side the percentage of attendance of pupils was 97 per cent.

DISCUSSION.

Chairman Hale: Gentlemen, you have heard the report of the committee. I believe it is more complete than any we have had relating to the subject. It is in the nature of tests which have been made in the West as well, and you probably have heard reports of the tests made out at the Normal School in Chicago, where they have attempted to get similar data only in one room, however, purely an experimental room, not in the complete school; but the chart they made was for the purpose of determining the most satisfactory temperature and relative humidity for rooms of that character, and was very similar to the one mentioned in the report here. About 65 degrees temperature and about 52 or 53 per cent. relative humidity was as near as they could get it during the test which they made two years ago. They had not determined that as a standard, but that is as far as their investigations had taken them. However, the results are very nearly what you have demonstrated.

Mr. Fielding: Mr. President, I believe that if a list of questions were made up and sent to Mr. Frank C. Goff, of Denver, Colorado, he could give some very good information on this same subject, but he will not give it unless you ask him the direct questions. He has experimented on these lines, and I know that he has information that is of great value.

Mr. Davis: Mr. President, I was struck with Mr. Cooper's report on Mr. Eveleth's paper in regard to the relative humidity in the dry end of the building; it strikes me as being remarkable. I remember about four years ago I had occasion to make some tests on the relative humidity of an office building. This building was heated with direct steam, and much to my surprise I found that the relative humidity in the corridors of that building was approximately 19 per cent. In the offices where they were occupied by from three to five people it would go a little higher. I think 23 per cent. relative humidity was as high as I found; and in some offices where there were only one or two people the relative humidity was practically the same as it was in the corridors. Now I cannot tell you just at this time what

the relative outside humidity was, but I presume it was somewhere around 70. The humidity in Baltimore usually runs a little higher than it does in most cities.

Mr. Whitten: I might call your attention to the fact that frequently the humidity becomes very low. During the week of February 5 to 12 the relative humidity is 10. This goes up to about 28, then drops back, and during the school period 18 to 20 is the range. We get here a fall and then a rise. The chart shows a fall that is undoubtedly due to a drop in the relative humidity outdoors from 82 to 43. The natural tendency under ordinary conditions for a schoolroom after a continued occupancy is for the humidity to rise, that is, in the dry side. When it appears to fall there is a reason for it. On February 9 the humidity runs from about 15 to 20. It rises for a short period to possibly 23; that is extremely low.

Mr. Chew: I have been sitting alongside of a hygrometer for some time, both in the home and in the office, and, while you say this report tells us about the effect of the humidity on the pupils, it also says there was a notable depression under certain conditions. These conditions have not been made clear, and they should be made clear by the committee. They understand the work pretty thoroughly, but they should make it clear to others. In the chart it is not made clear that the children were happier or better able to study with the humidity set at a given percentage. They kicked, if I understand the report right, when the humidity got down to a certain point or got above a certain point. But I am free to say I do not quite understand in this long talk what the point was.

Mr. Cooper: We could take perhaps the whole evening and part of to-morrow telling stories about what happened in that school, but we tried simply to give what perhaps a physician would ask us to give when we told them a story that was not a fact, because the discussion which arose here two years ago was on the subject of whether the engineers were giving conditions that physicians or physiologists had asked for. The question raised by Dr. Gulick was, are we getting the proper amount of ventilation in the modern heated and ventilated building? To Dr. Gulick it looked as if we were not, and a committee was appointed to work with your committee, from the American School Hygiene, to see if the engineers were providing the

proper conditions as far as the physiologists gave them conditions or standards to work on.

In this particular school, when the experiments were started, it was the intention that the teachers and the pupils should have no knowledge that an experiment of this kind was going on. They knew certain apparatus had been erected, but it was in both ends of the building and they were not told anything about it, and it was not until one day when the humidity became too great because the humidistat did not quite control it, that they began to discover that there were two ends to the building, one that was making an experiment different from the other. The idea was, a conclusion had been reached, and a conclusion that was backed up by this committee report and by what is now being done by the School Commission of the City of Boston. That the experiment resulted in such benefit to the school that teachers are crying for it, to use a common phrase.

Chairman Hale: Are there any further remarks that the members wish to make on this subject before that is put?

Mr. Wolf: Mr. President, I think we owe the committee our thanks for the thorough and systematic way in which they have made the investigations. They have simply investigated and found out the existing facts. It is easy to find fault with anything you don't know about, and, if this Society thinks as engineers we could suggest something that would remedy poor conditions, its members should do so. We have had a lot of talk about humidity and temperature. Sixty-five degrees is not a satisfactory temperature for the children of this country. They are used to living at home with temperature at 70 degrees, and putting them in a school room at 65 degrees they do not feel comfortable. What little experience I have had leads me to believe that maintaining a temperature of 70 degrees and humidity at 6 there will be no dry throats or coughs, and they will be comfortable. This, together with proper ventilation, will maintain the purity of the air within .006 of the outer air supply.

Dr. Billings, back twenty-five or thirty years ago, gave the relative values of the water-carrying power of air. It depends entirely on temperature. If I remember rightly, at 57 degrees the air will carry 1/80 of its weight in water. Every 27 degrees that you raise the temperature you double its water-carrying

power until you get up to 202, at which you get vapor, just before you get steam. And I think those figures are pretty nearly correct. I have no doubt that in some little time the humidity will be controlled with very much less cost than at present, and that the temperature and the humidity will be properly adjusted. Now, if you maintain a temperature of 70 degrees, and you can bring the humidity up to 6, you won't be far from feeling right.

Mr. Davis: Mr. President, I want to take exception to some things that Mr. Wolf has said about the school children in this country being used to 70. Some of them probably are, but some of them are probably more used to 45 than they are to 70. There are lots of school children that come from the poorer districts that do not have very good heating, in fact no heating at all in some cases. Now, so far as 70 degrees in the home is concerned, there are just as many different temperatures maintained in the homes in this country as there are different types of homes. Personally I had an amusing experience with a woman who claimed that her living room was unbearable, it was so cold. I went to the house and took a thermometer that was fairly correct, and I found a temperature of 85 degrees in the living room, and it was still too cold. She had a thermometer that she had bought at the ten-cent store that registered 59, and she was cold. She got rid of that thermometer and got one that was fairly correct, and after that she was thoroughly comfortable at 75.

Another lady, who lived in the same neighborhood, complained that 85 was not high enough for her. It was just about comfortable. She would like to have it a little bit warmer. So there isn't any standard temperature in the home. Now, my experience has been in the home that, where we find a temperature maintained under 70, we find people usually a little more vigilant. They seem to have more life in them. I know how it is in my own home. The very moment that the temperature gets up to 70 I begin to get uncomfortable. I get drowsy and sleepy if I get the temperature down to between 62 and 64. Around approximately 65 I feel considerably better. So, when we speak of a standard I personally think that a temperature of 70 degrees that we try and maintain in this country, I have thought for years is entirely too high.

Now, one word more, while I am on my feet. Mr. Cooper, with his consummate modesty, has asked for a vote of thanks for Mr. Eveleth. I want to amend that we include the entire committee, because I think that Mr. Cooper has done a great deal of work, probably as much as Mr. Eveleth. I want to include Mr. Cooper especially in the vote of thanks.

Mr. Wolf: I want to second that with just an explanation myself. I have been unfortunate enough to sign quite a few contracts. And I have always had to guarantee a temperature of 70 degrees, regardless of the outside temperature. I have worked up in Minnesota, Wisconsin and Michigan, where the temperature goes down to 40 and 60 below zero, but I had to guarantee 70 in the room. I never did much private work; it was mostly public buildings. Now, if I did not make good I did not get my money, and consequently I had to make good.

Chairman Hale: Mr. Cooper, do I understand that this report is reported to the Society as complete?

Mr. Cooper: As far as we have been able to go at this time, yes.

Chairman Hale: I think that clears up the point that Mr. Wolf is making. He feels that you pass this in as a complete report, while as a matter of fact it is only to tell what you have done so far, and, while you are still investigating, it is a complete report up to the present. It is progress.

CCCX.

OZONE AND ITS APPLICATIONS.

DR. M. W. FRANKLIN.

It is unfortunate that a subject which has so much real justification as has ozone should have been the victim of what should be considered a false start. A good deal of the literature on ozone, particularly in America, has been of the nature of advertising circulars for small apparatus which various firms have put upon the market, and the statements have been in a good many cases, to say the least, unbridled. The result has been what naturally might have been expected: a good many of those unsubstantiated statements have thrown discredit on a subject which, properly considered, is altogether worthy.

There is a justification for the small apparatus. They have an undisputable use and occupy a distinct field; but the difficulty has been misrepresentations, a non-understanding of the innate limitations of these devices, and the desire on the part of the exploiters to have them appear as therapeutic apparatus, apparatus capable of performing medical miracles. Of course, this view is preposterous, and sensible thinking persons have not been able to be rid of that feeling engendered by these statements: the result has been disastrous.

Ozone occupies a unique but unmistakable field in ventilation. It possesses a sphere, and while a good deal of thought has not been given to it in America, considerable advance has been made abroad, and in the few cases in which it has been applied here it has been successful where good judgment has been used in planning the installation.

I want to outline the theory of ozone. You are probably as familiar with that as I am. It is a modification of oxygen, but possesses the peculiarity of having greater activity than the ordinary atmospheric oxygen, so that the process of oxidation can

be attained at a relatively low temperature; this briefly outlines the whole subject. At any relatively low temperature, temperatures below those of combustion for most substances, these substances will oxidize in contact with ozone.

The ozone, of course, is not a means of obviating the necessity for ventilating system. While it might sound preposterous to you to have me even make the statement, I assure you I am frequently asked whether ozone cannot be used instead of ventilation, whether the ozone machine cannot be placed in a closed chamber and render the air wholly serviceable and viable for an indefinite period of time. Of course, this is preposterous. Some people imagine that the ozonizer is a machine to create oxygen, but it is not. The point is this: Ozone is useful in places where a result can be obtained with it that is not obtainable by other means, and, to make my explanation brief, I propose to give an example.

Take, for instance, a tannery, which actually represents a case which we have studied recently. A tannery where the emanations, the odors, constitute a nuisance to the neighbors. Now, it may be true that those odors are harmless, but it is a very hard thing to convince a neighbor that this is the case. A good many very elaborate systems have been worked out for collecting the effluvia at the different apparatus, different machines where it is created, and conducting it into an incinerating system, where it is destroyed by intense heat. These systems are more or less successful, mostly less. They are difficult of maintenance and expensive, and difficult to keep in operation all the time and very difficult to control in actual performance. In a case of that kind no amount of ventilation will render life, as far as the neighbors are concerned, any less intolerable.

The flow of the vast amount of effluvia into the air carries the nuisance to those who are obliged to breathe that air, and the fact that it may be diluted with an enormous quantity of air does not in any sense lessen the nuisance. It goes out into the air, with constant atmospheric changes of temperature, humidity and the like combined, which causes this odor to become as concentrated, at least in spots, as it was before it was diluted. Obviously this is no solution of the problem. The only solution heretofore has been, as stated, to render the rooms as nearly air-tight as possible, and to place elaborate ventilating schemes over the

openings of vats and pans, which cause this nuisance, and to collect this air and incinerate it. With ozone the result was very simply and satisfactorily attained. A certain amount of ozone which could be calculated with approximate precision—being introduced into the air in these rendering plants, glue factories, by-products plants, fertilizer plants or incinerating plants, renders innocuous the air which escapes—which must escape if there is to be a ventilating system. The odor can be destroyed so that it ceases to be a nuisance to anyone.

We have a case of the chimney of a fertilizer plant where the wind blew in a certain direction; the plant was proscribed by law from operation because it constituted a nuisance to the city and the neighborhood. The operators argued that the smell was harmless, but the people did not see it that way, and they were confronted with the necessity of either moving or conforming to the regulations of the health department; namely, operating only on such days when the wind blew the other way. Fortunately or unfortunately, they were situated on the ocean, but the wind blew with marvelous consistency in the direction of the city and the result was that they operated on what might be considered an unsatisfactorily small percentage of time. They talked of spending large sums to abate this nuisance, so that they could operate their plant continuously, and we assumed the contract. We put in an ozone plant, so that the gases going up this chimney which were objectionable, which constituted the nuisance, were mixed with ozone, and the plant has been operated full time since then, the wind making no difference. It can blow this way or that; there is no odor coming from that chimney.

We have another plant, a glue plant, up in Massachusetts, which had a similar experience. This plant occupied a small portion of the Massachusetts coast. It was as nearly forsaken as any place ever could be, but around them grew up a bit of a city, a bit of a town. The employees built their homes there, and some of them attained influence; some even got into politics, and, as the coast line was more or less attractive, certain summer residents erected beautiful so-called cottages; and behold, when the city became a success, due entirely to the nucleus, this glue plant, the aristocratic survivors suddenly realized that the glue plant was a nuisance, that it was not the correct thing to have around. They used to invite their friends out at the week-end and they

found the explanations tiresome; so they began to work to have the glue plant removed.

We got this problem and we took a vent chimney, I will not say where all the odors came out, but a place where we could definitely make a demonstration, and we injected ozone into this flue, and the flue is no longer a nuisance. People came from miles around to dilate on the nuisance that the chimney once was.

Take another instance. Suppose a tunnel, a subway tunnel, where at a certain point sewage sweeps through the walls and comes eventually into the tunnel. Assume that there is 600 or 1,000 feet between this point and the egress of the tunnel, and with the air passing in one direction, owing to the fact that trains are passing periodically. No amount of ventilation will abate that nuisance to the extent of immolating it. Between the place where the odor is created and the place where it must of necessity escape from the tunnel, there will exist a zone of—you can use any one of the adjectives to which you are accustomed in such cases. People passing through that area must inhale those emanations, and if they are human they will complain. In a case of that kind, assume that the requisite amount of ventilation is supplied, with the correct amount of air, a sufficient amount for the needs of the people, without going to gross extravagance in the matter of supplying more air than anybody can use. The injection of a small amount of ozone will absolutely abate the nuisance. Conditions are readjusted and the place is no longer a nuisance by the consensus of opinions of the persons who pass through.

Coming down to more personal cases, suppose you want to cook corned beef and cabbage. It is no business of your neighbors, to be sure, nevertheless it might be well to keep it from them. And here is a case where ozone can be used to good advantage. The ozone will render unnoticeable the odor of cooking cabbage or turnips or other things which some people are addicted to.

Take the case of factories where there are too many people in the place, where it does not seem possible, owing to various conditions and combinations of circumstances, to give any more than limited amount of space; and, in that case, even though there is plenty of ventilation, and pure air in the rooms at all times, passing through the rooms, the people between the fans and the door

used for exit for the air get the full benefit—the benefit with a negative sign, the minus sign. This can be greatly lessened by the introduction of ozone into the atmosphere.

I have tried to be general; I am not going to speak much longer, but the point is this: The ozone will reduce the odors in a way that ventilation cannot. There are cases, of course, where the thing can be taken care of entirely by proper ventilation; but there are cases, many of them in shops and in factories, where there are glue pots and consequently smells are injected into the air, of amyl-alcohol, varnish, and so forth, where no system of aspirating the atmosphere from the room will destroy the odor. Tunnels, glue factories, rendering plants, fertilizer plants, intestine dealers' plants, slaughter houses—cases multiply without limit where only the use of ozone can produce the result that is aimed at: namely, the destruction of the odor.

I might mention that the Atlantic Hotel in Hamburg, the very largest and best hotel in Germany, perhaps excluding the Adlon in Berlin, which I think very likely is somewhat smaller, has an ozone system. I will tell you how it is used there. They reckon that they have so many rooms there—all outside rooms, as all hotel rooms are. They get cold weather occasionally, and in the morning, when somebody has slept in one of these outside rooms, it becomes necessary to air it, because you could not force even a European peasant into one of those rooms that has been occupied. Now the great problem of airing these rooms stirs the hotelkeeper into active effort. If he does it becomes cold, and he very carefully and painstakingly, as is the case with Germans, calculates the square feet of surface in that room and the amount of furniture, and he takes the heat capacity of the different units, and figures that that room has a radiation of just so many calories. Then, by further calculation, knowing the efficiency or inefficiency of his heating system, he can determine how many pounds of coal it requires to heat up these rooms again to normal temperature.

With the ozonator with the amount of ventilation the room gets, the ordinary room may be totally and effectually deodorized, and in a very few minutes, the time depending on the system that is employed, the room is good enough to receive anyone. It seems as though it had never been slept in. This applies also

to the furniture and to the linen and other furnishings in the room.

The steamship *Imperator* is another instance. It is the greatest steamship in the world, bigger than the *Titanic*. It will be launched in May of this year. This ship is equipped from stem to stern with an ozone system, by which ozone is injected into the air, so that the amount of forced ventilation required is reduced greatly. That is to say, a very adequate, physiological amount of air can be used and this will fall far below the amount that has previously been considered necessary in similar circumstances.

The criticism has frequently been made that ozone masks other odors; that it is a case, to put it tritely, if inelegantly, of one smell covering up another. We recently have had occasion to investigate that subject fully and with extreme care, and think it has been proved beyond the peradventure of a doubt that the ozone actually destroys and in nowise masks these offensive odors. If I may have the blackboard a moment I will show you briefly what the procedure was, and you can judge yourselves whether my conclusions are justified or whether they are fanciful.

We used two glass bulbs similar in capacity, and a bell jar in which were placed different substances, the odors of which we wished to study. In the first instance a pound of complex substances, such as limburger cheese, sauerkraut, decaying meat, decaying oysters, decaying vegetables, boiled onions, raw onions, garlic, was taken and carefully and very slowly there was drawn through this substance, which was so arranged that the air must pass in below and above the substance to be studied—each substance was studied separately and alone—and then air passed equally into these two bulbs until we had in each bulb an amount of gas laden with the effluvia from these substances. When the bulbs each were full of the gas the connection was broken, and this vessel was connected with a tank containing ozonized air and pressure placed upon the tank so that an amount of air equal to the volume of this vessel was put in. In other words, we had in this vessel two atmospheres, two volume contents, one of the effluvium from the substances and the other of ozonized air, and into this other similar vessel there was introduced a volume of common atmospheric air without ozone. The thing was done

very carefully, so that there should be no ozone in this vessel, and we placed a trap in the way of the air, so that any ozone which might exist accidentally in the atmosphere would be destroyed. Thus we had essentially similar conditions in the two vessels: two atmospheres pressure, the same volume, effluvium of the same volume, but in one the ozonized air, and in the other the atmospheric air.

We presumed that ozone would act upon the effluvium chemically, and therefore we used an excess of ozone. That is to say, the concentration of ozone in this air was such that the total amount of ozone in the vessel would be greatly in excess of any conceivable amount that could be required. And then lest the excess of ozone deceive us by making the odor we introduced through a thistle tube in the one vessel which contained ozone, a solution of ferrous sulphate, which is readily oxidized, and again lest the ferrous sulphate have action on the odor, or give an odor of its own, so that the result would still be further disguised, we introduced into this other vessel a precisely similar amount of the same solution, so that the conditions in the two vessels were identical, with the exception that in the one there has been introduced ozone and into the other ordinary atmospheric air.

The ozone presumably would act upon the odor and in destroying it, consume itself. There would result a certain definite combination between the ozone and the odor and neither would remain *per se*. But there was an excess of ozone: and we put the solution of ferrous sulphate in, and lest that itself have an action on the odor we placed a similar amount in the check vessel and then opened the valve and tested the odor with the human nose, which is very sensitive, and in the case of my laboratory assistants highly calibrated, and we found in every case that the odor had totally disappeared in the ozonized bottle and that its effect became accentuated, owing to the pressure, in the other bottle. We could put on any pressure we wanted, and we were prepared to apply ten atmospheres, because we feared we might not be able to detect the smell, but we didn't need more than one atmosphere.

Dr. Crowder, sanitary expert of the Pullman Co., has suggested that there is one possible source of error. He does not believe that it is a source of error, but he thinks that in order to eliminate the last possible thread of a doubt, we should op-

erate at atmospheric pressure instead of two pressures. This will be tried. I would like to say that these tests were made alternately substituting one bottle for the other.

There is one other thing to be said. The question arises as to whether there are in the atmosphere organic poisons due to human exhalations. That question is a mooted one and there are two points of view held by different schools. As the question is open and as it has never been settled we will not attempt to settle it here. But I will say this: in no case is there any doubt that certain waste matters are capable of loading the atmosphere with something that may be tangible but which is at least perceptible to the sense of smell and that if it is not poison, if it is totally innocuous, if it is even pleasant, as we are forced to believe after listening to some arguments, at least we had better not have it present if it is not necessary. If we can render the air fresh and harmless scientifically and chemically why should we not do it?

We cannot prove by any definite system of logic whether the ozone really freshens the air or not, we cannot give any chemical or mathematical formula that proves it, any more than it can be proven that it does not. However, I have spoken to not fewer than two hundred persons who have existed in ozonized atmospheres; these people have comprised every class, from waitresses in some of the Boston restaurants to the chemists in charge of fertilizer plants; and they said that they felt better in the evening after going home. This is no ideal imagery, this is no figment of my imagination; it is a fact that everybody says he feels better when he works in that atmosphere of ozone than was previously the case. They do not feel so tired at five o'clock in the afternoon.

As to bacteria, we are still told that there are no bacteria in the air. This may be true, but in all my experience, whenever a sterile culture medium is exposed in an ordinary room and then incubated there will be obtained something that very closely approximates bacterial life. I have never seen it proven that there are no bacteria in the atmosphere and that no disease can be transmitted by the atmosphere. Furthermore, we have demonstrated absolutely that this same manifestation is lessened to the average extent of 88 per cent. by the injection into the atmosphere of an amount of ozone that is totally innocuous to human

beings, and that is incapable of producing any tangible manifestation of distress.

Speaking of the "feeling better at five o'clock," I heard one lady in London say, or rather I saw a letter which she has written after I had spoken to her about it, in which she wrote to Dr. Parshell, consulting engineer of the London Underground Railway system, and said that his subway tunnels, which were as vile as the Black Hole of Calcutta previous to the introduction of the ozonizing system, now were precisely the reverse and she was not ashamed to admit that she often sought the tunnel to get out of the rush and bustle of the crowd and to spend a quiet half hour there, that the air was fresh and invigorating.

After the address of Dr. Franklin there was quite a discussion on the part of the members and several questions were asked by those present, Mr. Jas. Davis, Dr. Colbert, Mr. Cooper, Mr. Myrick and Mr. Wolfe, after which Dr. Franklin replied as follows:

Dr. Franklin: About the physiological question, the effect on the heart beats, I want to say this: that first, from a purely theoretical consideration of the case, one mole, 48 gm. of ozone contains 32,000 cals. If you use a concentration of one volume in 2,000,000, you might possibly figure the amount of energy that a man gets into his system. About the heart beats, all you have to do is to take about five or six deep breaths and you can beat the heart beat effect of ozone all hollow. So most physiological experiments in which the greatly increased heart beat has been spoken of have been due to the fact that when anybody sniffs ozone he inhales deeply and then he says, "Gee! Feel my heart." Absolutely the dilutions that we make use of and the amounts assimilated are so small that the physiological effect can be considered as negligible, in the fullest sense of the word. It approaches that elusive quantity, the mathematical zero.

With respect to schools, wo are conducting experiments now. We have chosen in Schenectady some very beautiful examples of the kind of school children that have been mentioned and divided them into the sheep and the goats, taking two classrooms and ozonizing one and not the other, and Dr. Van der Bogert, who is an expert specialist on the diseases of children, proposes to conduct these experiments and will make very careful sta-

tistical observations on the general health, general intelligence and general performance of the children, and the general welfare, and needless to say, on their effluvia. I want to say further, too, that at a certain university a professor took a class in physics and examined them in a room which was ventilated in the ordinary way—and at a succeeding examination he had ozone in the room; and the percentage rating of students in the latter examination was increased very markedly. In the first case it was below 50, and in the second case it was above 90. It is needless to say that this result, standing alone is more in the position of the one swallow that does not make a summer. We are having tests performed by a number of universities, getting data, and they are in the hands of sufficiently enlightened persons to insure that the facts of humidity and atmospheric pressure, proportional breathing space, and a thousand and one things concerned are also being considered. I hope within a year to have at my disposal facts and figures which will be conclusive. Prof. Phelps, at the Massachusetts Institute of Technology, is also preparing to conduct experiments with his next series of examinations; and another man out west performed some experiments of a similar nature, in which, by the use of coffee, alcohol, nicotine and ozone as stimulants on many students, he found that the stimulation produced by the different stimulants was very different and that that of ozone approximated the ideal. That is to say, the stimulation increased very gradually and was maintained throughout the period, with no apparent falling off at any time. In the other cases the stimulation rose rapidly and the customary lag followed closely. The big curve of stimulation fell off, showing that it was purely artificial.

The amount of ozone that is used in any case is based on an arbitrary amount for a given set of conditions. I can outline only very briefly what we are trying to do. We say one volume in 2,000,000 as the maximum. Now we consider that each person must have not less than 500 cubic feet of space; that that applies to ordinary work at a desk—stenographers and men working in an office. If they have less space we increase the amount of ozone proportionately, if they have more space we decrease the amount of ozone. We also reckon that the air in the room shall be changed not fewer than three times an hour:

that is, in a room that has no system of ventilation, as an ordinary office.

In passing I would like to say that the ozone will find its application in a good many old-style buildings where the question of building in a ventilating system cannot be considered. Ozone will ameliorate the conditions, and if intelligently applied the conditions may be greatly ameliorated and the ozone finds there a justifiable application. It is probably not as good as ventilation, and certainly not as good as a combined system of ventilation and ozonizing; but in those cases where ventilation cannot be considered, for any one of many reasons which might arise, the ozone will improve greatly the existing conditions.

As to the physiological effects, I would say this: the useful amount of ozone is so small that people will rebel against its increase long before it is capable of doing any harm. They will not stand it in quantities sufficient to produce physiological harm. On the other hand, there are sensitive individuals who have strong imaginations, hysterical women and hypochondriacs. I recall a case in Philadelphia, which was brought to my attention, wherein a young lady who had gotten a whiff of ozone for the first time, fainted. She wrote in such unrestricted terms about it that I felt it necessary to go to Philadelphia and investigate. In the course of conversation with her she says, "I am very funny that way, you know. If I run up stairs I faint up there." And mildly leading her on I found that she was about the worst case of hysteria that I had ever seen. She was almost entitled to be locked up; and of course the minute she smelled this new odor she fainted and made herself very interesting to those around her.

As to the size of the ozonator, I will touch on that. We have tried and decided on certain standards, and in the course of time, when we shall have accumulated certain data, we will give out more details. We begin with one volume to 2,000,000 and then calculate backward and forward from this. We are tabulating the accumulated data, in connection with practice on the other side, and we hope in time to have an engineering system which will give precise results, but in the meantime the engineers have to consider each case individually.

In reference to the position of the heater and the ozone duct, the ideal condition is where the air from which the ozone is to

be manufactured comes in independently, and if cooled and properly dried, properly filtered, the ozone is formed in relatively high concentration. This air containing ozone is conducted into the air at some point beyond the rest of the system and mixed fully at the temperatures and conditions of proper concentration. We have to look into each case with respect to the economy, accessibility of the machine and nearness to water and of the electric supply system and one thing or another, and we try to arrive at this ideal condition.

As to the physiological experiments, we have investigated that which has been done in the medical laboratories from about 1845 to the present. There is probably nothing of scientific value in the exhibit at all. The best example of the effect of ozone in the man (myself) who had the misfortune to work for two years in an atmosphere of ozone, an atmosphere often several thousand times stronger than that recommended, and to my sorrow I have been gaining weight at the rate of about one per cent. a year.

The statement was made that nothing will oxidize better than oxygen. I have an experiment which will throw some light on that statement. In this I take a plate of steel, nice and clean, and polish it, and then have a little box one side of which is missing, the opposite side of which is glass. This is divided into two compartments and I place the steel mirror in the box so that it furnished the missing side, and is visible through the glass. Through one compartment pure dry oxygen is drawn, as pure as we can get it, chemically pure, and then through the other is drawn oxygen which is perhaps one-third of one per cent. ozone. The side of the steel subjected to the pure oxygen will remain a beautiful clear mirror as long as you have the patience to cause the oxygen stream to pass over it; while the other begins to cloud, as though one had breathed on it, and this intensifies till you have the beautiful phenomenon of rust. This shows that there is something that oxidizes more quickly than oxygen, and it is ozone.

Furthermore, we have the remarkable ozone water purification systems in Europe. In the very short period of three or four seconds every last item of bacterial life is destroyed in the water. No amount of oxygen would do it. The oxygen may do it in the course of two or three or four hours, but the cost

and length of time would be entirely prohibitive; and secondly, the dimensions of space necessary to enable it to handle the amount of water in a given time would make the system not to be considered practically. So I think that the ozone is justified as a bactericide. It is so considered by people who have had the opportunity to go into it more fully.

With respect to the destruction of bacterial fungoid growths, I want to say that that is one of the best applications of ozone, that is one of the clearest demonstrations of its value. In Germany every cold storage warehouse in course of time will have an ozone plant. It is spreading so rapidly that it is startling. Take these storage plants wherein they have placed an ozone producing plant at some convenient point. They close these plants and apply the ozone for an hour or so each day, and these plants are as clean as anything imaginable. I have seen one in Hamburg where they have 14,000,000 barrels of salt herring in one building. This building full of salt is in the middle of the city of Hamburg, and there is no more odor from this place than there is in the middle of this room now. The breweries use ozone in all their storage warehouses in all places where different perishable food articles are kept stored. Ozone is used to keep barrels of flour free from growths, and while I am on the subject I wish to say that the aspergillus niger who has yet an unfavorable opinion on this question, is absolutely destroyed by an incredibly small amount of ozone.

CCCXI.

THE DESIGN OF INDIRECT HEATING SYSTEMS WITH RESPECT TO MAXIMUM ECONOMY OF OPERATION.

BY FRANK L. BUSEY AND WILLIS H. CARRIER.

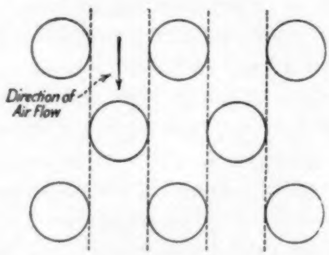
The subject of loss of pressure due to frictional resistance to the passage of air used for heating and ventilating purposes through heaters and piping or conduits is one that has received considerable attention on the part of many of those directly interested in this phase of engineering. On the other hand, there are many of those engaged in the installation of such apparatus who do not have a clear conception of the principles or relations involved or of their practical importance.

Heretofore the principal object striven for in making a heating and ventilating layout has been the attainment of the desired or specified results—generally at the lowest possible outlay for initial cost, and with but little or often no thought as to the future yearly outlay, either for power cost or for interest and depreciation loss. This utter ignoring of the economic results or economical operation possible in a properly designed apparatus frequently results in excessive frictional losses and consequent high yearly costs for power at the fan.

It will be the object of the present paper to show that there is a definite relation between the cost of power and the cost of the apparatus, and to determine what ratio between these two factors will insure the lowest practical yearly outlay to cover the cost of power, as well as an allowance on the cost of the installation to care for interest and depreciation. It may be shown that, according to present practice, velocities used are entirely too high for economical results.

There are two power requirements to be met at the fan of a fan-heating system, one due to maintaining the required velocity

head and the other depending on the loss in pressure due to the frictional resistance of the system. The first item is fixed when the velocities through the system are decided upon. The second item or requirement is due to two sources, the resistance through the heater, and the friction through the piping and ducts of the distributing system. These are two separate sources of pressure loss, and either one may be studied independently of the other and changes made, as one does not necessarily affect the other. Inasmuch as with a constant air quantity the friction loss varies as the square of the velocities of the air through the heater or ducts, it is seen that the resistance due to velocity is the factor to be considered in calculations relating to this subject.



SPACING OF PIPES IN FAN HEATER.

Although at the present time we have reliable data as to the rate of heat transmission under various conditions and also on the frictional resistance of heaters at different velocities, we have no rational basis for determining what velocities should be used from the standpoint of operating economy. That is a minimum of combined cost of maintenance and of power. At present the practice is to assume fan pressures arbitrarily, at say, ½, ¾ or 1 oz., and proportion the apparatus accordingly, so that the total pressure will not exceed the operating pressure at the fan. This is a good engineering basis for obtaining results, without respect to operating economy, and such a basis—now in general use by fan manufacturers—was first fully described in the treatise, "Heating and Ventilating," issued by the Buffalo Forge Company, in 1908.

FRICTIONAL RESISTANCE OF HEATERS

The frictional resistance of various pipe heaters will not vary greatly, except as may be due to difference in the spacing. Based on experimental data the most efficient spacing of staggered pipes seems to be where the distance between two consecutive pipes in a row is exactly equal to the diameter of the pipe, as shown by the accompanying sketch.

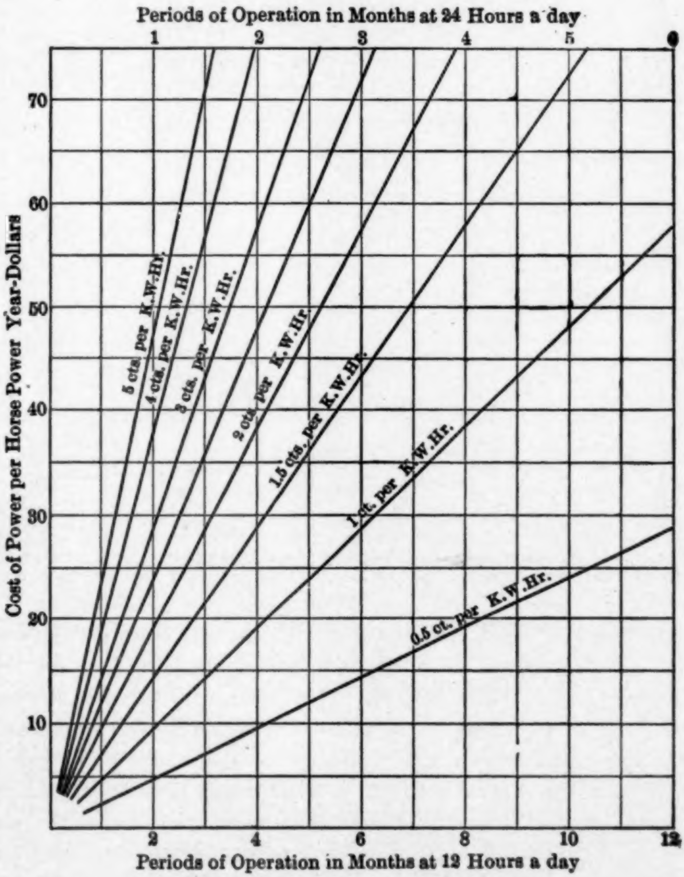


FIG. 1.—COST OF POWER PER HORSE-POWER-YEAR AT VARIOUS PRICES FOR POWER AND PERIODS OF OPERATION.

In general the law seems to hold that the rate of heat transmission varies with the frictional resistance of the heater. The relative efficiency of two heaters should be based on the rate of heat transmission under identical temperature conditions and with *equal pressure losses* in forcing the air through the heater, and not upon the so-called velocity through the clear area, which is more or less of a hypothetical quantity.

The limiting factors for such an installation, from an engineering standpoint, are speeds for the fan and engine that will be

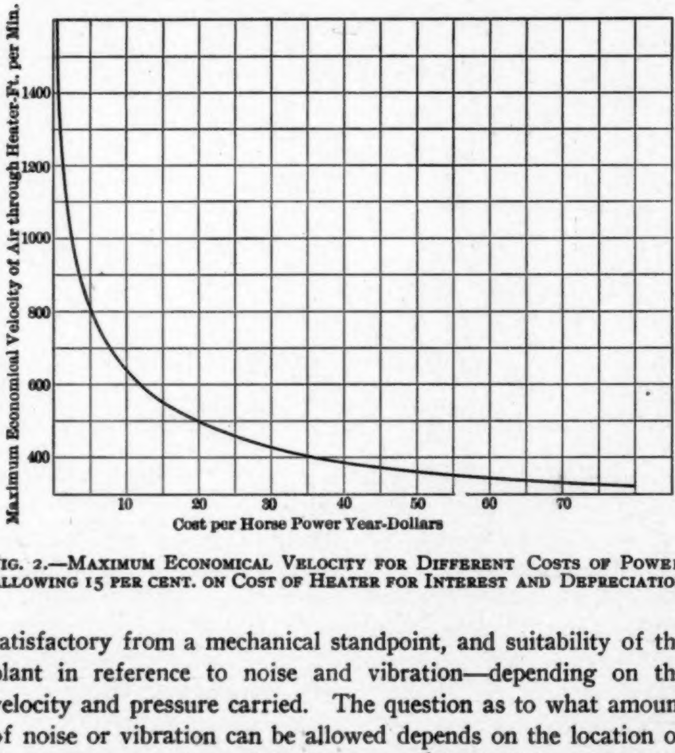


FIG. 2.—MAXIMUM ECONOMICAL VELOCITY FOR DIFFERENT COSTS OF POWER, ALLOWING 15 PER CENT. ON COST OF HEATER FOR INTEREST AND DEPRECIATION

satisfactory from a mechanical standpoint, and suitability of the plant in reference to noise and vibration—depending on the velocity and pressure carried. The question as to what amount of noise or vibration can be allowed depends on the location of the apparatus and on the character of the building. For instance, in the case of a school or auditorium, if the apparatus is located in the basement, a limited amount of noise might not be as objectionable as if the fan was in quarters adjoining, or above a room used by the occupants of the building. In such a case the pressure at the fan should be limited to ½ to ¾ oz.,

depending on the circumstances. On the other hand, where a fan is installed in a shop or factory, noise and vibration may become a matter of secondary consideration, and a pressure at the fan of one ounce or more allowed.

Instances have been called to the writer's attention where makers of heating apparatus, either through ignorance or wilful intention to mislead, have assumed a velocity through a six-section heater of 1,500 ft. per minute, running the fan at ¾ oz.,

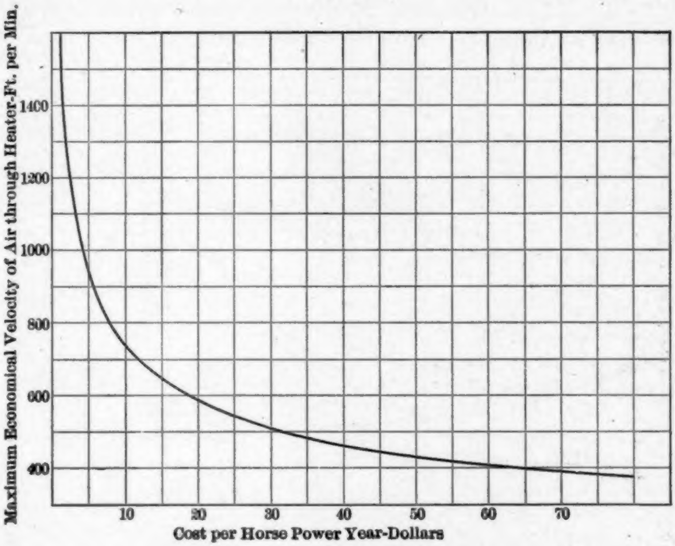


FIG. 3.—MAXIMUM ECONOMICAL VELOCITY FOR DIFFERENT COSTS OF POWER, ALLOWING 25 PER CENT. ON COST OF HEATER FOR INTEREST AND DEPRECIATION.

or approximately 1 in. static pressure. The pipe resistance was probably not less than ¼ to ½ in., leaving from ½ to ¾ in. for the resistance of the heater, whereas the actual resistance through the heater at the assumed velocity would be about 1.3 in. This means that the fan would actually be handling under these conditions from 70 to 84 per cent. of the amount of air specified. In other words, the effective heating capacity of the apparatus would be only from 70 to 84 per cent. of the capacity represented.

Any decrease in the velocity of the air through the heater means an increase in clear area with a decreased rate of trans-

mission and a consequent increase in total surface required. It also reduces the friction and therefore the horse-power required at the fan, with an increase in the size of the fan and a decrease in the size of the motor. To get the same heating effect the depth of the heater must be inversely proportioned to the square root of the total surface, or directly, as the square root of the rate of transmission is determined by the velocity. The horse-power and the pressure loss vary directly as the seven-thirds power of the velocity when the heater is proportioned to give the same temperature rise to the same quantity of air. The for-

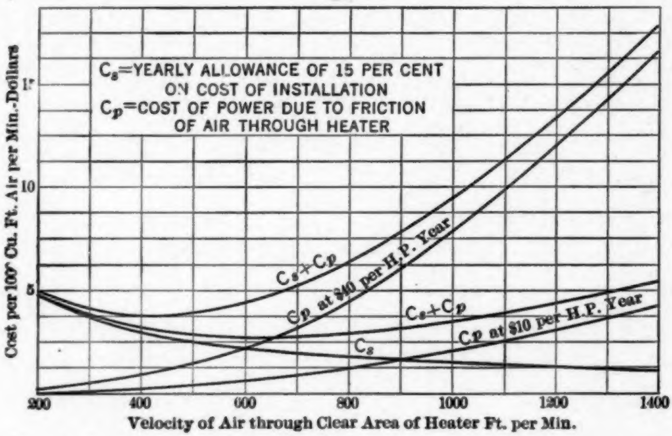


FIG. 4.—RELATIVE YEARLY INTEREST AND DEPRECIATION COST OF SURFACE AND POWER COST DUE TO FRICTION OF AIR THROUGH HEATER AT VARIOUS VELOCITIES THROUGH THE CLEAR AREA, ALLOWING 15 PER CENT. ON COST OF HEATER FOR INTEREST AND DEPRECIATION.

mulæ expressing these relationships, together with their derivation, will be found in Appendix No. 1.

It might be well to suggest in this connection that increasing the surface of the heater by the use of the additional sections will not answer the purpose intended, as this would increase the pressure and power required. The increase in surface must be obtained by using larger sections with the greater clear area, so as to handle the same amount of air at the reduced velocity, using the same temperature rise.

The method already mentioned of assuming a total pressure against which the fan is to operate and then so proportion the

various pressure losses as to keep within this limit fails to take into consideration the element of power cost at the fan. That this is an item of more than secondary importance will be shown, together with the relation of the cost of installation to the sub-

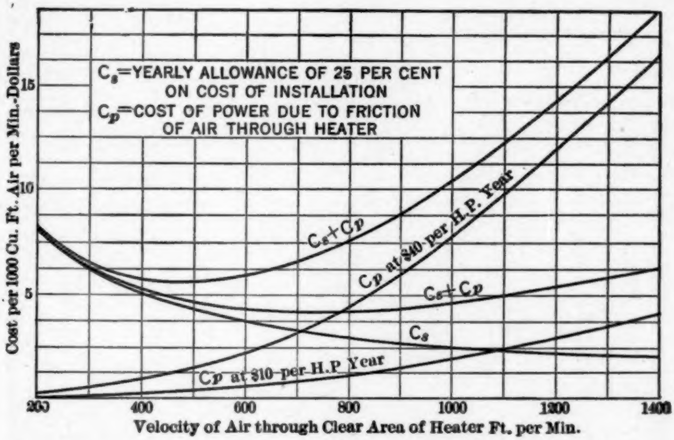


FIG. 5.—RELATIVE YEARLY INTEREST AND DEPRECIATION COST OF SURFACE AND POWER COST DUE TO FRICTION OF AIR THROUGH HEATER AT VARIOUS VELOCITIES THROUGH THE CLEAR AREA, ALLOWING 25 PER CENT. ON COST OF HEATER FOR INTEREST AND DEPRECIATION.

sequent cost of power. These are two items of cost to be considered, and the relation between them will be shown for various conditions.

VELOCITY FOR MAXIMUM ECONOMY.

Assuming a static efficiency of 40 per cent. for the fan—that is, 40 per cent. of the brake horse-power consumed by the fan is usefully employed in moving the air against static resistance—the horse-power required due to any resistance or pressure drop through the heater will be the product of the air handled times the pressure drop expressed in inches of water times a constant, 0.000405. Expressed as a formula this becomes

$$H = 0.000405\, p\, Q \qquad \text{(A)}$$

The yearly cost for the power consumed in overcoming the resistance will be the product of this horse-power times the

yearly cost per horse-power. The yearly allowance on the cost of the installation for the interest and depreciation may be varied according to circumstances, the probable limits being 15 to 25 per cent. yearly for any ordinary installation. As will be shown, these relations may be expressed by a series of formulæ and any specified case analyzed.

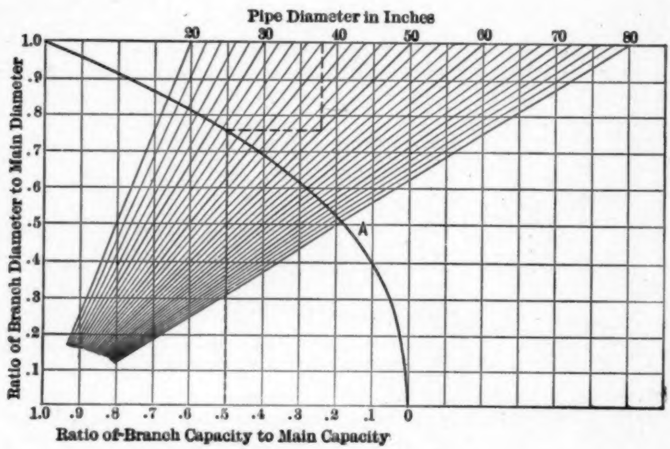


FIG. 6.—PROPORTIONING PIPING TO ALLOW FOR FRICTION.

Letting C_p represent the total year cost of power at the fan, and m the cost per horse-power year, we will have

$$C_p = 0.000405 \text{ m p Q} = \text{m H} \qquad \text{(B)}$$

Also letting C_s represent the yearly charge for interest and depreciation, based on the cost of the heater, and S the total square feet of surface in the heater, we will have C_s = s, times the allowance per square foot for interest and depreciation.

Letting C_{po} and C_{so} be the respective costs at any assumed velocity, V_a, through the clear area, and C_p and C_s be the corresponding costs at any other velocity, V, we have

$$C_s = C_{so}\left(\frac{V}{V_o}\right)^{\frac{3}{5}} \qquad (14)$$

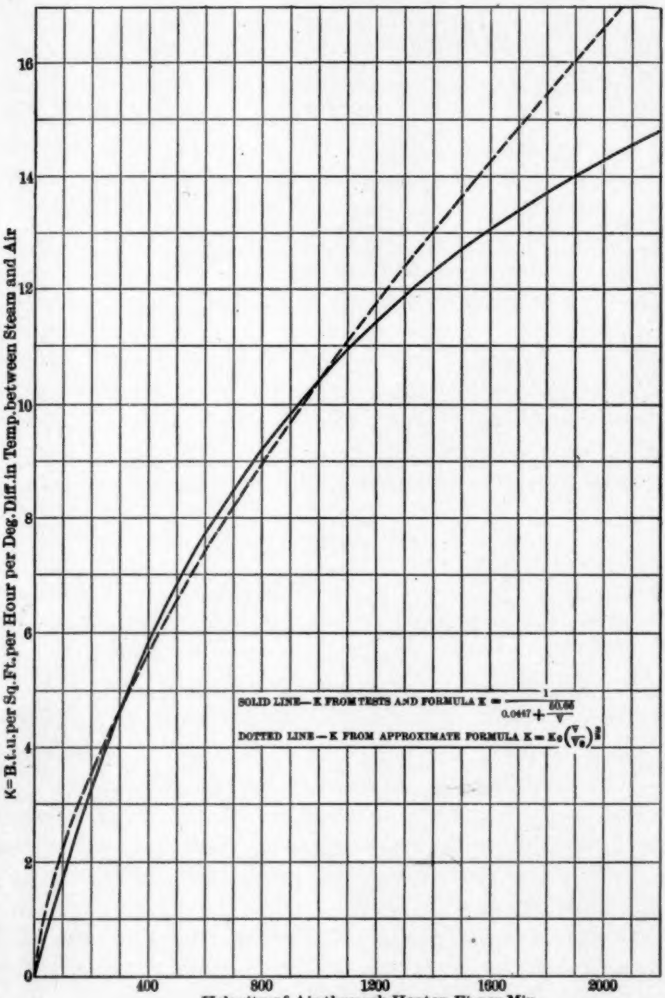


FIG 7.—RATE OF HEAT TRANSMISSION FROM TESTS AND FROM FORMULA

$$K = K_0\left(\frac{V}{V_0}\right)^{\frac{2}{3}}$$

and
$$C_p = C_{po}\left(\frac{V}{V_o}\right)^{7/3} \tag{15}$$

For proof of these relationships, see Appendix No. 1.

We also have
$$\left(\frac{V_m}{V_o}\right)^3 = 0.286\left(\frac{C_{so}}{C_{po}}\right) \tag{19}$$

and
$$V_m = 0.66\ V_o\left(\frac{C_{so}}{C_{po}}\right)^{1/3} \tag{20}$$

If the assumed velocity V is also the most economical velocity, then $V_o = V_m$ and
$$\left(\frac{V_m}{V_o}\right)^3 = 1$$

Assuming then, that the chosen velocity is that which gives maximum economy, we have from equation (19)
$$0.286\left(\frac{C_s}{C_p}\right) = 1$$

or
$$C_p = 0.286\ C_s \tag{C}$$

This means that for the most economical installation the yearly cost of the power consumed in overcoming the friction of the heater should be 28.6 per cent. of the annual cost of the heater; that is, annual interest and depreciation allowance based on initial costs. This very interesting relationship is clearly proved in Appendix No. 1.

We may also see that the velocity through the clear area for the maximum economy is independent of the depth required, temperature rise, or the steam pressure. That is, if we increase the depth of the heater to give the greater temperature rise it is evident that the cost of power and the cost of the heater are each increased in exactly the same proportion, since they both increase exactly in proportion to the increase in the depth of the heater. Hence the value of V_m remains unchanged.

PRACTICAL APPLICATION

These relationships of surface, velocity and power cost, due to the resistance, may best be shown by means of a specific ex-

ample, to which the accompanying curves apply. Any other assumed conditions may be treated in the same manner.

As frequent reference will be made to the cost of power per *horse-power year* at the fan, due to forcing the air through the heater against the frictional resistance, Fig. 1 is given to show the relation between this unit and the common one of cost per kilowatt hour. Across the lower edge of the diagram are laid out the periods of operation in months of twelve hours a day, and across the top months of twenty-four hours a day. Any combination of operating periods may be found on these scales. The diagonal lines represent the cost of power in cents per kilowatt hour and the left edge the corresponding cost per horse-power year.

Thus, a plant operating four months a year and twelve hours a day, with power costing 2.5 cents per kwhr., will be paying \$47.50 a year per horse-power. If power costs 1 cent per kwhr., the horse-power will cost \$20 a year. As already shown, the cost per year due to the frictional resistance of the heater will be

$$C_p = (0.000405\ p\ Q)\ m = H \times m$$

where m is the cost per hpyr.

Take for example a case where 30,000 cu. ft. per minute is to be warmed from zero to 103 deg., by means of a Buffalo pipe coil heater. Assuming for convenience a velocity of 1,000 ft. per min., through the clear area, we will require a heater five sections or 20 rows of pipe deep, with 184.3 sq. ft. of surface per section. The loss of pressure due to the frictional resistance will be 0.48 in. Then

$$Q_o = 30000$$

$$V_o = 1000$$

$$S_o = 184.3 \times 5 = 921.5 \text{ (sq. ft.)}$$

$$p = 0.48 \text{ (in.)}$$

Operating four months a year at 12 hr. a day, with power costing 2 cents per kwhr., the yearly cost of power will be \$40 per horse-power. Then the horse-power required will be

$$H = 3000 \times 0.000405 \times 0.48 = 5.83$$

and $$C_{po} = 5.83 \times \$40 = \$233 \text{ a year.}$$

Allowing 15 per cent. on the cost of the installed heater for interest and depreciation on a cost of 35 cents per square foot, we will have

$$C_{so} = 921.5 \times \$0.0525 = \$48.4 \text{ a year.}$$

Then the maximum economical velocity for these conditions will be given by equation (20)

$$V_m = V_o \times 0.66 \left(\frac{C_{so}}{C_{po}}\right)^{\frac{1}{3}}$$

$$= 1000 \times 0.66 \times 5925 = 391 \text{ ft. per min.}$$

Substituting the various costs per hpyr., in the above formula, we may determine the corresponding maximum economical velocity for each case, and these values plotted, as in Fig. 2. From this curve may be determined V_m for any intermediate power cost.

From Fig. 2 it may be seen that, if a return of 15 per cent. is desired on the investment, in order to use a velocity of 1,000 ft. per min., the power should not cost more than $2.50 per hpyr. This would only be the case where the fan was driven by a steam engine, and the exhaust steam used in the heating coils, practically using the engine for a reducing valve.

Fig. 3 shows the same relation of power cost to velocity when 25 per cent. is allowed for interest and depreciation. The curve is similar to that in Fig. 2, but shows the greater velocity allowable under this condition.

The curves in Figs. 4 and 5 show the general relation between the cost of the power due to the frictional resistance through the heater at the two rates of $10 and $40 per hpyr., the interest and depreciation allowance on the cost of the heater and the sum of these two, or the total yearly charge. For Fig. 4 an allowance of 15 per cent. is made for interest and depreciation, while for Fig. 5 this allowance is 25 per cent. The cost of power is the same for each set of curves, but the combined curve $(C_s + C_p)$ is different, due to the difference in the value of C_s.

The curve $C_s + C_p$ represents the combined cost per 1,000 cu. ft. of air per min., due to the interest and power cost for the

different velocities. From Fig. 4 we see that if power costs $40 per hpyr., the lowest total cost of operation will be $3.75 per 1,000 cu. ft. per minute, at a velocity of 400 ft. per min., through the heater. It may be easily noted from the curve how the increase in velocity makes an increase in cost. The velocity at the low points on these total cost curves should correspond to the velocity from the curve in Figs. 2 and 3 for the same cost per hpyr. The two values of $10 and $40 per hpyr. are taken merely as two representative costs, and the curves may be plotted for any other horse-power cost or interest allowance by means of equations (14) and (15).

The assumed values used in making the calculations for Figs. 2 and 5 are not intended to apply to all cases, although they do probably represent average conditions. The price per square foot for the heater installed complete, with casing and steam and drip headers, will vary more or less with every case, but 35 cents was taken as a fair value and near enough to most installations to form the basis for a comparative study. The percentage allowance for interest and depreciation may be varied to suit the circumstances, and will depend largely on how much the purchaser's money is worth to him; that is, whether he would be satisfied with a return of 5 or 6 per cent. on this investment, or whether, by putting the money into his business he could make several times that return.

PRESSURE LOSSES IN PIPING SYSTEM

The losses in the piping system are made up of two parts, the dynamic losses and the friction losses. The dynamic losses are due to changes, either in the direction or velocity of the air flow, and are composed of the loss of entrance and of the loss in elbows and connections. The first is the pressure required to produce velocity itself in the pipe, and may vary anywhere from 1 to 1.5 times the velocity head, *i. e.*, the pressure corresponding to the velocity, depending on whether the pipe is connected directly to the fan outlet or through a plenum chamber. It is expressed as a multiple of the pressure corresponding to the average velocity produced in the pipe. Where the velocity in the pipe is the same as at the fan outlet this may still be considered a loss, in view of the fact that with a reduction of velocity through

a gradually diverging outlet to a larger area the difference between the velocity head at the fan and the velocity head in the pipe is largely utilized by conversion to static pressure.

The other chief source of dynamic loss is in the elbows, and depends on the radius of curvature of the elbow and not on the size of the elbow or the velocity of the air. This loss may be expressed directly in per cent. of the velocity-head, and, with a round, five-piece elbow, having a center line radius of one diameter, the loss will be 25 per cent. of the average velocity-head. With a five-piece elbow having a center line radius of one and one-half diameters the loss will be 17 per cent., or only two-thirds that of the first case. This shows the advantage of an intelligently designed system and the possibility in power saving, for the elbows may be of so short a radius as to cause the loss of an entire velocity-head in each elbow.

An instance recently came to the writer's notice that will serve as an illustration of the effect of a badly built layout, inasmuch as the apparatus was used in connection with a manufacturing installation, and the effect of the elbow resistance was directly evident in curtailed production. Two different sets of similar apparatus were installed under the same conditions, except that in one, the piping connections were properly constructed, while in the other there were four sharp right-angle elbows used. The outfit with the easy long radius elbows is in successful operation, while in the other the output of the apparatus is probably not more than one-half of what it should be and of what the properly installed plant is doing. The piping in both cases is the full size of the fan outlet, and the only difference is the construction of the elbows.

The second source of pressure loss in the piping system is due to the friction of the air against the sides of the pipe. This loss will vary directly as the length of the pipe, or as the square of the velocity, and inversely as the diameter of the pipe. As the length is a fixed quantity for any system, the only factors subject to modification are the diameter and velocity, which determine the relation between the power cost and the piping cost.

As in the case of the heaters, it is the usual engineering practice to proportion the piping arbitrarily, either from assumed velocities depending upon the velocity of the air at the fan outlet, or, in better engineering practice, by determining the velocity

which will give an assumed resistance considered suitable and within the fan capacity. It is the usual practice among fan manufacturers gradually to decrease the velocity of the air in the main conduit, as the latter is decreased in size, owing to partial delivery of the air through the branch outlets.

This practice serves three useful purposes:

1. A proper proportioning of the velocities permits a uniform delivery of the air through all of the branch outlets without dampers and regardless of the distance from the fan.
2. By a gradual reduction in velocity a considerable proportion of the velocity pressure is usefully converted to static pressure, thus largely compensating for the piping friction.
3. It decreases the friction in the smaller piping, where it would otherwise be the greatest.

The method which probably accomplishes this the most satisfactorily, and at the same time in a thoroughly practical manner, is that introduced by the Buffalo Forge Co., and described in its treatise on "Heating and Ventilating," issued in 1908. In this method the sizes of the branches or reduced piping may be proportioned directly from the assumed size of the main pipe without calculation by referring to the accompanying chart, Fig. No. 6.

For example, assume we have a branch intended to carry 50 per cent. of the capacity of the main pipe, which is 50 in. in diameter. Starting at the bottom of the chart with 50 per cent. capacity, we pass upward until we intersect the line A, thence horizontally until we strike the diagonal line marked 50, thence upward to the scale at the top of the chart, which gives us a diameter of 38 in. for the branch pipe. This then is so proportioned as to give us the same friction per foot of length as in the main pipe. This permits the resistance of the entire system to be calculated as though it was of one diameter, with a corresponding velocity throughout its entire length.

VELOCITY FOR MAXIMUM ECONOMY

A decrease in velocity increases the size and cost of the air conduit, but decreases the cost of power consumed in overcom-

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As in the case of the heaters, it is the usual engineering practice to proportion the piping arbitrarily, either from assumed velocities depending upon the velocity of the air at the fan outlet, or, in better engineering practice, by determining the velocity

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VELOCITY FOR MAXIMUM ECONOMY

A decrease in velocity increases the size and cost of the air conduit, but decreases the cost of power consumed in overcom-

ing the conduit or piping resistance. From a point of economy the question to be determined is what relation between power cost and conduit cost, as determined by the velocity, will give the minimum annual total cost.

This relationship is shown in Appendix No. 2 to be

$$\left(\frac{V_m}{V_o}\right)^3 = 0.335\left(\frac{C_{wo}}{C_{po}}\right) \tag{41}$$

or

$$V_m = 0.7\ V_o\left(\frac{C_{wo}}{C_{po}}\right)^{\frac{1}{3}} \tag{42}$$

Where C_{po} and C_{wo} represent respectively the cost of power to overcome piping resistance and the annual allowance on the cost of the piping for interest and depreciation at an assumed velocity V_o, and V_m is the relative velocity required for maximum economy.

Comparing these relationships with those obtained for the heater, it is evident that they are almost identical. It will be seen in this case that for the maximum economy the annual cost of power consumed by piping resistance should be practically one-third of the annual interest and depreciation charges, based on the initial cost of piping. That is, $C_p = 0.335\ C_w$ for maximum economy.

PRACTICAL APPLICATIONS

For the purpose of illustrating the application of the foregoing principles to a system of galvanized iron piping different cases will be assumed and the results shown. A system handling 30,000 cu. ft. per min., at a velocity of 1,950 ft. per min., will require a pipe 53 in. in diameter, or an area of 15.32 sq. ft. These quantities will be taken as a constant condition, but different arrangements considered in the system of piping.

Assuming one straight duct 200 ft. long and 53 in. in diameter, delivering all of the air at the end farthest from the fan, we will have two sources of loss to be overcome by the fan. First, the dynamic loss due to the velocity of 1,950 ft. per min. (or one velocity-head), and second, the loss due to friction, amounting to one velocity-head in each forty diameters of length. The pressure due to the velocity of 1,950 ft. per min.

in the pipe (one velocity-head) will be 0.237 in., water gauge. The loss of pressure due to friction will be

$$\frac{200}{4.42 \times 40} = 1.13 \text{ velocity head.}$$

This loss expressed in inches of water will be

$$0.237 \times 1.13 = 0.257 \text{ in.}$$

and the total loss will be the sum of these two, or 0.494 inch. In the piping system a part of the velocity is converted to static pressure, hence the power calculation should be based on total pressures with a corresponding fan efficiency of 50 per cent. At a rate of $20 per hpyr., the annual cost due to the piping resistance will be

$$C_{po} = 30{,}000 \times 0.000324 \times 0.494 \times 20 = \$96.$$

A round galvanized iron pipe, 53 in. in diameter, would be made of No. 18 iron, weighing 2.3 lb. per sq. ft., and would contain 14.2 sq. ft. per running foot. This would make 32.7 lb. per running foot, o- a total of 6,540 lb. for the entire pipe. Allowing 25 per cent. annually for interest and depreciation on an initial cost of say, 10 cents per pound, the yearly allowance would be 2.5 cents per pound of iron. Then we would have as the yearly allowance for interest and depreciation

$$C_{wo} = 6540 \times \$.025 = \$163.50$$

From equation (42) we may determine that for the most economical conditions the velocity of the air in the pipe should be

$$V_m = 0.7 \times 1950 \left(\frac{163.5}{98.0}\right)^{\frac{1}{3}} = 1620 \text{ ft. per min.}$$

Assuming the case where the 30,000 cu. ft. per min. is to be uniformly distributed by a galvanized iron pipe 200 ft. long, with equal openings every 20 ft. of its length, each discharging 3,000 cu. ft. per min., we will have an example of another common form of installation. Referring to the chart, Fig. 6, we see that, if the first 20 ft. of pipe is 53 in. in diameter, the next 20 ft. carrying 90 per cent. of the air should be 51 in. in diameter. Treating each successive section in the same manner we may determine the diameter and weight of each section, and will

find the total weight of the piping to be 3,922 lb. Then the yearly total allowance for interest and depreciation on the piping system will be

$$C_{wo} = 3922 \times .025 = \$98.05$$

The loss in pressure due to friction will be the same as in the first case considered, or 0.257 in., but the loss due to the velocity will be only about 40 per cent. of the loss, as calculated in the first example, or 0.095 in. The total pressure loss will then be

$$0.257 + 0.095 = 0.352 \text{ in.}$$

and the annual power cost at $20 per hpyr. will be

$$C_{po} = 30{,}000 \times 0.000324 \times 0.352 \times 20 = \$68.50$$

As before, from equation (42) we will have as the velocity for the most economical operation

$$V_m = 0.7 \times 1950 \left(\frac{98.05}{68.50}\right)^{\frac{1}{3}} = 1540 \text{ ft. per min.}$$

Another example of the application of the relationship herein presented would be to assume a case of an entire installation of fan, heater and piping. As already suggested, a probably fair average annual allowance on the entire apparatus for interest and depreciation would be 20 per cent. on the first cost of the installation. Assuming that, in order to obtain the most economical operation the yearly cost of power should be 30 per cent. of the above 20 per cent. allowance, we have the yearly power cost as equal to 6 per cent. on the initial cost of the installation. Allowing $20 per hpyr. as the cost of power, we will find from Fig. 3 that, with a 25 per cent. allowance in the cost of the heater for interest and depreciation, the velocity through the heater should be approximately 590 ft. per min. in order to operate at the point of greatest economy.

For the same assumed conditions as to air handled, the resistance through the heater will now be 0.145 in. and at the most economical velocity through the piping system the pressure loss will be 0.31 in., making a total pressure at the fan of

$$0.145 + 0.31 = 0.455 \text{ in., or } 0.254 \text{ oz.}$$

The total annual cost of power will then be

$$C_p = \$98$$

instead of \$212.50 under the first assumed conditions when using one straight run of pipe 200 ft. long. This would show a saving of \$114.50. The total cost of the apparatus as at first assumed would be approximately \$1,331, so that the power cost of \$212.50 would amount to 16 per cent. on the initial cost of the apparatus.

The total cost of the apparatus, as revised to meet the more economical conditions, would be \$1,660, or an increase of \$329. The yearly cost of power would be 5.9 per cent. on the initial cost, and we would have an allowance of 19.7 per cent. for interest and depreciation on the entire installation. The saving of \$114.50 would make a return of 35 per cent. on the additional investment.

CONCLUSION

Based on the foregoing deductions it is evidently not only possible but practical to lay out a heating and ventilating system in such a manner as to obtain any desired economic results with as much certainty as is at present done with regard to the strictly engineering features.

As regards the heater, the most economical point will be reached when the installation is so proportioned that the yearly cost of power due to the frictional resistance of the heater amounts to 28.6 per cent. of the annual interest and depreciation allowance on the first cost of the heater. This is true regardless of variations in the depth of heater, temperature rise or steam pressure.

The most economical velocity through the piping or conduits is such that the annual cost of power due to the piping resistance is one-third of the annual allowance for interest and depreciation. This latter may be assumed to be about 25 per cent. on the original cost of installation.

While these lower velocities and consequently lower resistance would require the use of larger fans in order to operate at high efficiency, considering the entire installation of heater, piping and fan, the annual cost of power should be practically 30 per cent.

of the total annual allowance for interest and depreciation. If this allowance is taken at 20 per cent. as an average, we would have 6 per cent. on the first cost as the most economical yearly rate to be allowed for power.

Appendix No. 1.—Derivation of Formulæ. Pressure Loss Through Heaters.

In the following formulæ we will let

S = total surface in heater.
n = number of units depth in heater.
p = pressure loss in heater.
$\frac{p}{n}$ = pressure loss per unit depth corresponding to velocity V.
$\frac{p_o}{n_o}$ = pressure loss per unit depth corresponding to velocity V_o.
$\frac{S}{n}$ = surface per unit depth corresponding to velocity V.
$\frac{S_o}{n_o}$ = surface per unit depth corresponding to velocity V_o.
K = rate of transmission in B.t.u. per square foot.
V = velocity of air through clear area.
H = horse-power at fan.
Q = cubic feet air per minute.
m = cost per horse-power per year.
C_p = yearly total cost of power consumed due to heater resistance.
C_s = yearly interest and depreciation allowance on heater.

Since the pressure loss per unit depth of heater varies as the square of the velocity through the clear area.

$$\frac{\frac{p}{n}}{\frac{p_o}{n_o}} = \frac{pn_o}{p_on} = \left(\frac{V}{V_o}\right)^2 \qquad (1)$$

Also since the surface per unit depth of heater for a given volume of air varies inversely as the velocity through the clear area, we have

$$\frac{\frac{S_o}{n_o}}{\frac{S}{n}} = \frac{V}{V_o}$$

hence

$$\frac{pn_o}{p_on} = \left(\frac{V}{V_o}\right)^2 = \left(\frac{S_on}{Sn_o}\right)^2 \qquad (2)$$

Coefficients of Heat Transmission at Various Velocities.

Velocity through heater.	K from tests.	$K = K_o\left(\frac{V}{V_o}\right)^{\frac{2}{3}}$
200	3.35	3.58
400	5.86	5.68
600	7.72	7.45
800	9.20	9.03
1,000	10.46	10.46
1,200	11.49	11.80

Value of K_o taken as K at 1,000 velocity.

As shown in the accompanying table the rate of heat transmission K as determined by experiment varies approximately as the two-thirds power of the velocity through the clear area. This formula was first proposed by Mr. Burt S. Harrison, using the experimental data published by the Buffalo Forge Company, in its treatise on "Heating and Ventilating": "Air Conditioning Apparatus," American Society of Mechanical Engineers, December, 1911, by Willis H. Carrier and Frank L. Busey; and "Heat Transmission with Indirect Radiation," American Society of Heating and Ventilating Engineers, January, 1912, by Frank L. Busey. The relation between these two values of K is more clearly shown by the curves in Fig. 7.

Hence

$$\frac{K}{K_o} = \left(\frac{V}{V_o}\right)^{\frac{2}{3}} \text{ (approximately)} \qquad (3)$$

But the amount of surface required for a given heating effect will vary inversely as the rate of heat transmission.

Hence $$\frac{S_o}{S} = \frac{K}{K_o} = \left(\frac{V}{V_o}\right)^{\frac{2}{3}} \text{ (approximately)} \tag{4}$$

By taking the cube root of the members of equation (2) we have

$$\left(\frac{V}{V_o}\right)^{\frac{1}{3}} = \left(\frac{S_o n}{S n_o}\right)^{\frac{1}{3}} \tag{5}$$

hence $$\frac{S_o}{S} = \left(\frac{S_o n}{S n_o}\right)^{\frac{2}{3}} \tag{6}$$

$$\left(\frac{S_o}{S}\right)^{\frac{1}{3}} = \left(\frac{n}{n_o}\right)^{\frac{2}{3}} \tag{7}$$

and $$\frac{S_o}{S} = \left(\frac{n}{n_o}\right)^2 = \left(\frac{V}{V_o}\right)^{\frac{2}{3}} \tag{8}$$

also $$\frac{n}{n_o} = \left(\frac{V}{V_o}\right)^{\frac{1}{3}} \tag{9}$$

Equations (8) and (9) therefore establish the relationship between the required surface, units depth of heater, and velocity for any specified heating effect.

Substituting the above value of $\frac{n}{n_o}$ in equation (2) we have

$$\frac{p}{p_o} \left(\frac{V_o}{V}\right)^{\frac{1}{3}} = \left(\frac{V}{V_o}\right)^2 \tag{10}$$

hence $$\frac{p}{p_o} = \left(\frac{V}{V_o}\right)^{\frac{7}{3}} \tag{11}$$

But since the power and the cost of the power required to deliver a fixed quantity of air against a resistance varies directly as that resistance, we have

$$\frac{C_p}{C_{po}} = \frac{H}{H_o} = \frac{p}{p_o} = \left(\frac{V}{V_o}\right)^{\frac{7}{3}} \tag{12}$$

Also since the cost of heater is directly proportional to the surface we have from equation (8)

$$\frac{C_{so}}{C_s} = \left(\frac{V}{V_o}\right)^{\frac{2}{3}} \tag{13}$$

and $$C_s = C_{so} \left(\frac{V_o}{V}\right)^{\frac{2}{3}} \tag{14}$$

From equation (12)

$$C_p = C_{po} \left(\frac{V}{V_o}\right)^{\frac{7}{3}} \tag{15}$$

The total cost

$$C = C_{po} \left(\frac{V}{V_o}\right)^{\frac{7}{3}} + C_{so} \left(\frac{V_o}{V}\right)^{\frac{2}{3}} \tag{16}$$

The total cost is a minimum when the first differential of the second member of this equation is zero. Therefore for a minimum total cost we have

$$\frac{d\left(C_{po}\left(\frac{V}{V_o}\right)^{\frac{7}{3}}\right)}{dV} + \frac{d\left(C_{so}\left(\frac{V_o}{V}\right)^{\frac{2}{3}}\right)}{dV} = 0. \tag{17}$$

hence $$\frac{7}{3}\left(\frac{C_{po}}{V_o^{\frac{7}{3}}}\right) V^{\frac{4}{3}} - \frac{2}{3} C_{so} (V_o)^{\frac{2}{3}} \left(\frac{1}{V}\right)^{\frac{5}{3}} = 0 \tag{18}$$

Substituting Vm as the value of V for maximum economy in the above equation we have

$$\left(\frac{V_m}{V_o}\right)^3 = 0.286 \left(\frac{C_{so}}{C_{po}}\right) \tag{19}$$

and $$V_m = 0.66\ V_o \left(\frac{C_{so}}{C_{po}}\right)^{\frac{1}{3}} \tag{20}$$

APPENDIX No. 2.—DERIVATION OF FORMULÆ. PRESSURE LOSSES IN PIPING SYSTEM.

In the following formulæ we will have

p = pressure loss in inches water gauge.
p_f = pressure loss due to friction.
p_d = pressure loss due to dynamic losses.
f = constant.
l = length of pipe in feet.
d = diameter of pipe in feet.
V = average velocity of air in pipe.
C_p = yearly cost of power consumed due to piping resistance.
C_w = yearly allowance on cost of piping for interest and depreciation.

We may express the loss in pressure due to friction in handling a given quantity of air at a given velocity through a given length of pipe by the formula

$$p_f = \frac{fV^2l}{d} \tag{21}$$

Assuming one velocity head lost in forty diameters length, with air at approximately 140 deg., we will have

$$f = 0.00000000135$$

We may express the dynamic losses as

$$p_d = X\left(\frac{V}{4300}\right)^2 \tag{22}$$

where X is the number of velocity heads lost in the entire system.

From the equation (21) we have

$$\frac{p_f}{p_{fo}} = \frac{V^2 d_o}{V_o^2 d} = \left(\frac{d_o}{d}\right)^5 = \left(\frac{V}{V_o}\right)^{\frac{5}{2}} \tag{23}$$

$$\frac{C_p}{C_{po}} = \frac{p_f}{p_{fo}} = \left(\frac{V}{V_o}\right)^{\frac{5}{2}} \tag{24}$$

and

$$C_p = C_{po}\left(\frac{V}{V_o}\right)^{\frac{5}{2}} \tag{25}$$

It will be found by investigation that the average cost of round iron piping will vary closely as the square root of the diameter, as shown by the accompanying table.

Average diameter of pipe for given gauge.	Square root of pipe diameter.	Weight of gauge used.	Ratio of column 2 and 3.
15	3.9	1.00	3.9
25	5.0	1.30	3.85
35	5.9	1.50	3.93
45	6.7	1.75	3.83

Hence we have

$$\frac{C_w}{C_{wo}} = \frac{d}{d_o}\left(\frac{d}{d_o}\right)^{\frac{1}{2}} = \left(\frac{d}{d_o}\right)^{\frac{3}{2}} = \left(\frac{V_o}{V}\right)^{\frac{3}{4}} \tag{26}$$

and

$$C_w = C_{wo}\left(\frac{V_o}{V}\right)^{\frac{3}{4}} \tag{27}$$

The total annual cost chargeable to piping will be

$$C_p + C_w = C_{po}\left(\frac{V}{V_o}\right)^{\frac{5}{2}} + C_{wo}\left(\frac{V_o}{V}\right)^{\frac{3}{4}} \tag{28}$$

Since the total cost will be a minimum when the first differential is equal to zero, we will have for a minimum annual cost,

$$\frac{d\left(C_{po}\left(\frac{V}{V_o}\right)^{\frac{5}{2}}\right)}{dV} + \frac{d\left(C_{wo}\left(\frac{V_o}{V}\right)^{\frac{3}{4}}\right)}{dV} = 0 \tag{29}$$

hence

$$\frac{5}{2}\left(\frac{C_{po}}{V_o^{\frac{5}{2}}}\right)V^{\frac{3}{2}} - \frac{3}{4}C_{wo}\,(V_o)^{\frac{3}{4}}\left(\frac{1}{V}\right)^{\frac{7}{4}} = 0 \tag{30}$$

Substituting Vm for V in the above as representing the velocity for maximum economy we have

$$\left(\frac{Vm}{Vo}\right)^{\frac{13}{4}}=0.3\left(\frac{Cwo}{Cpo}\right) \tag{31}$$

and

$$Vm=0.691\ Vo\left(\frac{Cwo}{Cpo}\right)^{\frac{4}{13}} \tag{32}$$

Considering dynamic losses only from equation (22) we may derive

$$\frac{pd}{pdo}=\left(\frac{V}{Vo}\right)^{2} \tag{33}$$

That is

$$\frac{Cp}{Cpo}=\left(\frac{V}{Vo}\right)^{2} \tag{34}$$

and

$$Cp=Cpo\left(\frac{V}{Vo}\right)^{2} \tag{35}$$

From equation (27)

$$Cw=Cwo\left(\frac{Vo}{V}\right)^{\frac{3}{4}} \tag{36}$$

As before the total cost will be a minimum when

$$\frac{d\left(Cpo\left(\frac{V}{Vo}\right)^{2}\right)}{d\ V}+\frac{d\left(Cwo\left(\frac{Vo}{V}\right)^{\frac{3}{4}}\right)}{d\ V}=0 \tag{37}$$

hence

$$2\left(\frac{Cpo}{Vo^{2}}\right)V-\tfrac{3}{4}Cwo\ (Vo)^{\frac{3}{4}}\left(\frac{1}{V}\right)^{\frac{7}{4}}=0 \tag{38}$$

Substituting Vm for V in the above as representing the velocity for maximum economy we have

$$\left(\frac{Vm}{Vo}\right)^{\frac{11}{4}}=0.375\left(\frac{Cwo}{Cpo}\right) \tag{39}$$

and

$$Vm=0.699\ Vo\left(\frac{Cwo}{Cpo}\right)^{\frac{4}{11}} \tag{40}$$

But since in the average piping layout the dynamic and frictional losses are approximately equal we may assume an approximate formula which will be intermediate between equations (31) and (39) as follows:

$$\left(\frac{Vm}{Vo}\right)^{3}=0.335\left(\frac{Cwo}{Cpo}\right) \tag{41}$$

Hence approximately

$$Vm=0.7\ Vo\left(\frac{Cwo}{Cpo}\right)^{\frac{1}{3}} \tag{42}$$

DISCUSSION.

Mr. Chapman: I would like to ask what allowance is made for space conditions; that is, the loss of rental due to the extra space taken up by the apparatus, due to its use with low air velocities. Also the possible proportionate cost of building that that feature would bring in.

James H. Davis: Does the formula given provide for different spacings from center to center of the pipes in the heater?

Mr. Harding: I would like to ask on what the authors based their friction factor of 40, whether that was derived from ex-

perimental results or whether it is the well-known formula $40L \div D$. Our experiments have shown that this factor varies from 61 to 71 on all pipes up to 64-in. in diameter.

Mr. James A. Donnelly: I would like to see some addition made to this paper giving calculations in regard to the size and speed of the fan and its effect upon the heating system. It is probable that the cost of operating the fan has more to do with the selection of either a direct radiation system or a hot blast system than anything else. Of course, there is the necessity of operating a fan when the direct radiation is shut down, but the proportionate cost for power in relation to the size of the system, where the power is purchased from the outside, is really a direct source of increased power load. In some of the larger railroad shops, for instance, the determination has been made to use direct radiation heating systems rather than hot blast recirculating systems, in order to keep down the power load, so that the power station capacity would not be exceeded. A few years ago the practice was to run up the speed of the fans to just about their limit and to reduce the size of the mains to a minimum. To-day, the speed of the fans is far lower and the motors are correspondingly very much larger, being operated at reduced speeds. In an installation in a Waterbury, Conn., church, I remember that a committee of the church declared that the high air velocities pulled the gravel off the street over a grass plot for a distance of 100 ft. They had something like a 440-volt circuit when the fan was first in operation, and I apologized when I changed it down to a 110-volt circuit. Where we had used something like 14 or 16 h.p., it dropped down to 3 or 4 h.p. That was 20 years ago.

Mr. McCann: This is very interesting, but I do not see that it applies where you have use for the exhaust steam; for instance, for a steam engine driving blowers; because the cost of power there is practically nothing. I would like Mr. Busey to say what he thinks on that point.

Mr. Busey: As to the allowance for space and the consequent extra cost of the building, in such buildings as factories, where the ducts are swung overhead through the girders, this would not be an important item. The main increase in size, however, would be in the heater. Still that would not be enough larger to call for much extra room.

Replying to Mr. Davis' question about applying the formula to different spacings, I have done so with different spacings of pipes and also with the Vento heaters. The horse-power varies directly as the friction loss, and knowing the friction loss through any heater, this same formula can be applied with the same results.

The question as to how many diameters of pipe length may be considered equivalent to one velocity head in friction loss has been given considerable attention. I am accustomed to vary this factor anywhere from 40 to 60, depending upon the character of the installation and the purpose for which it is used. For ordinary heating work where the pipe is swedged and contains dampers, reducers, and other obstruction, I consider a factor of 40 diameters as conservative. Where I know the conditions to be favorable I would say 50. For planing mill or other exhaust system where the piping is made as smooth as possible and considerable care has been used in its erection I would use a factor of 55 or 60, but seldom higher.

In regard to the question as to cost of power, it may be noted from the curves that the cost of power at the fan is a vital factor. The point of particular interest in most cases, especially where we are buying power, is that the cost of power goes up very much more rapidly than the cost of service comes down with increased velocities.

In answer to Mr. McCann's question, it may be noted from the curves that when the fan is driven by a steam engine and the exhaust used in the heating coils, the velocity used may be relatively higher. It is all a matter of how much your power is costing and as suggested, in a case like the above, the power is practically gratis. But it must be remembered that in schoolhouses and public buildings it is not advisable to run at too high a velocity on account of the danger of noise. Frequently ½ oz., and at most ¾ oz., is all that can be allowed. But when the power costs are high it is evident that it pays to use a larger apparatus and keep the velocities down. I have in mind the case of an isolated schoolhouse where current cost 9 cents per kilowatt hour, and the contract was let to a firm proposing a large apparatus just because they were able to show a possible saving in power consumption.

CCCXII.

REPORT OF COMMITTEE ON PROPOSED STANDARDS FOR VENTILATION LEGISLATION FOR MOTION PICTURE SHOW PLACES.

Ventilation and sanitation requirements cannot be too strongly emphasized when dealing with the question of legislation relating to motion picture show places. The widespread neglect, in a very large number of communities throughout the country, of proper ventilation and sanitation in such motion picture show places, has many times been correctly characterized as a "menace to public health"—materially affecting the moral tone as well.

Allowing the great importance of fire protection and structural requirements for the protection of *life;* elimination of low-class vaudeville, enforced lighting during performances, supervision of pictures exhibited, and other essential matters for the protection of *morals;* ventilation and sanitation requirements loom up large for the protection of *health.*

The Committee has been appointed to deal with the subject of ventilation and this question is, of course, vitally concerned with all the conditions of the air breathed, particularly *temperature, air purity, air motion, humidity,* and *freedom from dust* (impurities from breathing, skin exhalations, dust, etc., being constantly released in large quantities in every audience hall).

With a view of suggesting minimum requirements that are practical to secure, the following recommendations are made as standards for legislation to cover this important phase of the needed general regulations for motion picture show places.

MINIMUM VENTILATION STANDARDS

1. *Floor Area Per Occupant.*

A *minimum* of 4⅓ sq. ft. of floor area, as a seating space, per occupant, exclusive of aisles and public passageways, shall be provided in the audience hall.

2. *Cubic Space Per Occupant.*

A *minimum* of 80 cu. ft. of air space, per occupant, shall be provided in the audience hall.

3. *Quantity of Outdoor Air.*

A supply of outdoor air from an uncontaminated source shall be provided the audience hall at all times while the show place is open to the public, and the quantity of this positive supply of outdoor air shall be based on a *minimum* requirement of 15 cu. ft. per minute, per occupant.

4. *Temperature.*

The temperature of the air in the audience hall shall at all times, while the show place is open to the public, be maintained throughout at the breathing line (persons being seated) within the range of 62 deg. F. to 70 deg. F. (except when the outside temperature is sufficiently high not to require the air supply for ventilation to be heated). The temperature, distribution, and diffusion of the supplied outdoor air shall be such as to maintain the temperature requirement without uncomfortable drafts.

5. *Direct Heat Sources.*

Any good heat source which does not contaminate the air will be accepted to supplement the warmed outdoor air supply. Gas radiators are prohibited.

6. *Machine Booth Ventilation.*

Enclosures or booths for the motion picture machines shall be provided with special exhaust ventilation with a capacity to exhaust at all times not less than 60 cu. ft. of air per minute through a one-machine booth, not less than 90 cu. ft. of air per minute through a two-machine booth, and not less than 120 cu. ft. of air per minute through a three-machine booth.

This ventilation shall include a number of small metal screened openings (equipped with special dampers and automatic appliance with fusible link to automatically close tight in case of fire in the booth) on the sides of the booth near the bottom of same, aggregating 180 sq. in. for a one-machine booth, 210 sq. in. for a two-machine booth, and 240 sq. in. for a three-machine booth; and this booth exhaust ventilation shall also include a metal or other fireproof flue, extending from the top or side at the top of the booth, and carried to a proper place

of discharge outdoors and augmented by mechanical appliance or otherwise, to secure the results of handling at least the quantity of air as herein stated as minimum.

The size of this special fireproof vent flue shall be not less than 96 sq. in. clear area for a one-machine booth, not less than 120 sq. in. clear area for a two-machine booth, and not less than 144 sq. in. clear area for a three-machine booth, and this special vent flue shall be provided with an adjustable damper, operated from the booth, and equipped with an automatic appliance and a fusible link to operate so as to open the damper wide automatically in case of fire in the booth. The machine booth ventilation shall be kept in operation at all times when the booth is in use.

:——— o ———:

General questions, such as inspection, method of enforcing the requirements, penalties for non-compliance, etc., are left for each state, town, or city to determine, although some suggestions covering these matters are made in the following general remarks:

:——— o ———:

It will be noted that the foregoing regulations are simple, and that violations may be readily detected, also that care has been exercised to leave large latitude for design of the ventilating apparatus.

It should be especially noted that the foregoing regulations call for a *minimum* of all requirements as compulsory, and that it should be the aim of the administrative department having enforcement of the regulations in charge to encourage motion picture show owners and managers to provide as comprehensive, liberal, and high-class equipment as possible, with a view to catering to the comfort and health of the patrons and thus add to the popularity of the show place as compared with others which may have barely come within the legal requirements.

The minimum of 4⅓ sq. ft. of floor area per occupant called for by the recommended legislation regulations considers the seating space to be 32 in. back to back of seats, with a width for an individual seat of 19½ in. The 32 in. has been demonstrated as desirable to provide for reasonable passageway. The general regulations would probably cover these dimensions.

The 80 cu. ft. of air space per occupant, called for by the recommended regulations, has been arrived at as a *minimum* cubic space per individual under which fairly good air conditions can be secured, and it will be noted that this requirement, when taken in conjunction with the floor space requirement, automatically provides that the ceiling height in the small show place will average about 16 ft. in the clear, under minimum floor space requirements.

Elimination of dust from the air supply by means of air filters or air washers is desirable under the best conditions and is imperative under some conditions of especially dusty air supply. This question is dealt with by suggestion in the following general clauses.

The controlling of relative humidity is desirable, whenever possible, but the Committee decided to omit from the regulations any humidity requirement.

The machine booth ventilation, as per recommended regulations, would be greatly improved, especially for summer conditions, by providing a duct connection from out of doors to the bottom of the booth, for the introduction of outdoor air directly to the booth, such a duct to equal in size the special exhaust duct referred to in regulations for the different sizes of booths, should be made of metal and should pitch from the booth downward to the outside wall of the building and be provided at the inlet with a weather-protection hood. An adjustable damper should be placed in this duct connection near the booth, under control in the booth and independently equipped with an automatic appliance and a fusible link to operate so as to close automatically in case of fire in the booth.

Strong emphasis is placed on the need of having the administrative feature of legislation of the kind here advocated, placed in the control of a responsible department, such as a State Board of Health in the case of villages, but preferably some other responsible local department for cities, and that such department be supplied with a special inspector or inspectors, experienced in heating, ventilation, and sanitation, and that such department be given reasonable latitude by legislation, such as to require approval of plans preceding installation or to require special extra equipment for special cases, such as dust filters for air supply where the air supply is especially dust laden; exhaust

ventilation of toilets where building laws do not properly cover this matter; fans in the auditorium, to keep the air in motion where diffusion is insufficient, etc., it being made clear in the legislation that such latitude should in no case include the right to reduce the stated minimum requirements. The administrative department should also be given the support of other local or state departments, as the case may be, such as the fire department, police department, health department, etc.

Definite penalties, such as fines for minor offenses, up to a suspension or revoking of licenses for important or repeated violations, are certainly indispensable to get practical results.

When it is realized that in New York City alone over 300,000 (nearly one-third of a million) individuals attend motion picture show performances *daily;* that in an average audience hall without ventilation the air is constantly being rebreathed, to say nothing of various other contaminations of the air: and that high temperature of air, with its debilitating effects, is very difficult to prevent, except through the medium of ventilation, a greater demand will be made on the part of the public for proper ventilation.

FRANK T. CHAPMAN,
BERT C. DAVIS,
JOSEPH GRAHAM,
THOMAS BARWICK,
J. W. H. MYRICK,
E. L. HOGAN,
W. W. MACON,

COMMITTEE.

DISCUSSION.

Before reading the report of the Committee, the chairman, Frank T. Chapman, made the following remarks:

"In preparing this report, the Committee has included, in addition to the recommended standards, some general remarks and suggestions, which are intended mainly to be suggestive to those in different communities undertaking to arrange for legislation to regulate motion picture show places, whose information in regard to the question of ventilation may be limited and yet who are desirous of getting the best practical results. This aspect is taken with the thought that if the Society approves the standards suggested the general remarks and suggestions will be helpful."

After the report of the Committee had been read there was

some general discussion, in which the necessity for prompt action was emphasized on account of the urgent need throughout the country of intelligent suggestion on which to base ventilation legislation. On motion of Mr. Blackmore, it was decided that the Council have the report printed and a copy mailed to each member of the Society, together with a brief of the discussion, for expression of opinion by mail vote, and that an opportunity be given for suggestion or comment by the members.

Vice-President Hale, during the discussion, pointed out that, while those present realized that the Committee had made a very careful investigation of the subject, one danger of a vote by mail was that other members of the Society not present may not have gone into the peculiar difficulties presented in undertaking to secure ventilation for motion picture show places and might therefore vote contrary to the best interests of the Society and the public welfare, notwithstanding the fact that the Committee had made a *thorough investigation and was capable of passing on the subject.*

Secretary Macon spoke at some length in support of the report of the Committee, in part, as follows:

"This report is something that helps to align a society of this kind as meeting and fulfilling the duty that it owes to the general public. The report is something of which many copies may be printed and sent to all town councils, villages and other bodies which have this problem in hand. The report includes a preamble and explanation of the general features, and anything that attempts to improve the conditions of the atmosphere of a motion picture show place does influence the things apart from ventilation itself. You can readily imagine that if we had a number of such pamphlets in the hands of our members and a large number of them in the Secretary's office, we could do a great deal of good in the town council which is considering some sort of legislation and needs some authoritative advice.

"Here is a society which is supposed to know the most there is to know of a very important part of the equipment and operation of motion picture show places. * * * * In other words, this is a signal opportunity for an engineering society to do something for people outside of the membership, and that is what every engineering society ought to exist for.

"Naturally you cannot get publicity in the papers because the

public is not accustomed to reading such equations as we had this morning. It is up to us to translate those equations and put them into language which will interest the layman. In this connection, I think there is only one way in which we could discuss the report properly and that is to take it up section by section. We will have something to send to our members in the way of a brief of the discussion for their guidance in voting."

Mr. Myrick emphasized the advantage of avoiding any requirements of specific design of apparatus, advocating in place thereof, as in the case of this report, particular requirements of results to be obtained, such as temperature, quantity of fresh air, distribution and diffusion of air, etc., leaving wide latitude as to the design of the equipment to secure the required results. Mr. Myrick called attention to the close seating conditions in motion picture show places and the consequent serious danger of the spread of disease.

Mr. Chapman quoted from a report on the Condition of Moving Picture Show Places in New York, as made by the Commissioner of Accounts, March, 1911, as follows:

"The majority of the 50 places examined were found to be badly overcrowded, in some instances with the aisles completely blocked by standing spectators, so that it was impossible for our inspectors to force their way into the hall. The ventilation in most of the places was wretched, no air being admitted except such as came through the front doors. In many places attendants went through the room with an atomizer, spraying perfumery on the crowd to allay the odor."

Mr. Chapman also quoted from the same report comments of inspectors illustrating the condition which was found to exist in motion picture show places, as follows:

"*Third Avenue, Manhattan:* This is a vile-smelling place, and an attendant went round with a big pump atomizer, spraying perfumery to allay the odor."

"*Pitkin Avenue, Brooklyn:* Seats full and about 250 standing in the rear and in the aisles. A critical inspection of this place was impossible. The crowd was surging back and forth, pushing and shoving for vantage points of view. Quarrels were frequent. The air was fetid and stifling. Children under 16 years of age were admitted unaccompanied. This place is without one single redeeming feature."

Mr. Chapman also stated: "In connection with this I just want to say for the Committee that, while it does not for a moment undertake to say that this report cannot be improved upon, it feels that there is a distinct opportunity just at this time, by approving this report after such discussion as may come out, to give it reasonably wide circulation, and have it reach places where there is an undertaking at this time to legislate on these matters. Motion picture show places are being built very rapidly all through the country, as we all know, and the time is ripe for action. In fact, it would have been much better if we had taken action a year ago on this point, in order that our work might have had still more practical results in the line of service."

Dr. William F. Colbert stated as his view and conclusion, after giving much thought to the subject, that upward ventilation has a peculiar value in particularly crowded places, and that of all places a motion picture show place presents those conditions.

In the actual discussion of the minimum ventilation standards, section by section, as appearing in the report of the Committee, the following ideas were brought out:

Professor Kent asked why a minimum of 4⅓ sq. ft. of floor area as a seating space per occupant was named as against a greater or less area.

Mr. Chapman referred to the general clause in the report indicating that 32 in. back to back of seats had been demonstrated as desirable to provide for reasonable passageway, the other dimension of the seating space being 19½ in. minimum. Mr. Chapman further stated: "The reason why the Committee decided on the suggestion of 4⅓ sq. ft. of floor area for the seating space is that in connection with securing ventilation for motion picture show places the space conditions come into play and are important. The cubic contents of the room are important and the seating space is important. The Committee investigated a number of moving picture show places, also secured information from many sources, with a view to making these conditions reasonable and practicable.

"The requirement of 32 in. back to back of seats seems to be generally accepted now as a matter of experience to be the best

distance considering a reasonable passageway in view of the constant change of audience. There are many picture places where the distance is less than 32 in. back to back of seats, but the best information the Committee was able to get has settled for it the idea that 32 in. is reasonable to suggest, and the space conditions are therefore based on that distance. I might say that the Folk Ordinance, now under consideration in New York City, calls for a distance of 32 in. back to back of seats. The distance of 19½ in. in width of seat is, in the judgment of the Committee, the minimum in which a person can sit comfortably. The idea of the Committee is to avoid giving the exact dimensions in ventilation requirements, stating square feet of area instead, because it feels that it is a question that does not belong to heating and ventilating. The Committee did feel that, in view of the cubic contents being very important, it was important also to make this general requirement as a seating space which would in a measure be an explanation on the face of it, to those considering legislation, in construing the requirement as a practical thing for enactment. I might say right here that these two questions of floor area per occupant and cubic space per occupant belong together, so far as any discussion goes.

"Referring to the minimum of 80 cu. ft. of air space per occupant, I would refer you to the general clause of the report dealing with the matter, as follows: 'The 80 cu. ft. of air space per occupant, called for by the recommended regulations, has been arrived at as a minimum cubic space per individual, under which fairly good air conditions can be secured, and it will be noted that this requirement, when taken in conjunction with the floor space requirement, automatically provides that the ceiling height in the small show places will average about 16 ft. in the clear under minimum floor space requirements.'"

Mr. Capron made the statement that the Chicago Commission had adopted the uniform name of "Picture Theatres" as representing all classes of moving picture show places, and advanced the idea that it might be well for the Society to conform to that name, or ask the Chicago Commission to change the name it had adopted.

Mr. Chapman: The Committee report heading uses "Motion Picture Show Places." The idea was to cover motion picture show places of any sort and in any locality, whether they are in

theater form, in a store remodeled, or in whatever class of building is regularly used for the purpose of motion picture shows. The title "Picture Theatres" would hardly, in the opinion of the Committee, cover the case.

Mr. Williams: I would like to know why 15 cu. ft. per minute per occupant was selected?

Mr. Hinkle inquired if the physicians who were asked last year for their opinion on the proper amount of air to supply for ventilation had made any reply.

Professor Kent: Most school ventilation laws require 30 cu. ft. of air per minute for each pupil, and pupils average under 15 years of age. I believe that most authorities say that an adult requires more air than a youth. Why do you allow the adults of these motion picture show places only half as much as the school laws provide for scholars?

Mr. Baldwin suggested making the requirements of air supply per seat, rather than per occupant, in order to avoid the possibility of reducing the total air supply to correspond with the number of persons in the audience at any particular time.

Mr. Miller asked why it would not be well to call for a certain number of changes of air per hour in the audience hall, instead of making a requirement of 15 cu. ft. per minute per occupant.

Mr. Chapman: In dealing with these questions we must bear in mind that the Committee has tried to suggest for legislation something that in the first place will not call forth too much opposition and criticism when it comes up before a legislature, town council, or other body, and which will not be so drastic as to prevent it being enacted at all, and that, in the second place, will be reasonable in requirement and practical from the standpoint of ventilation.

The first question was why we settled upon 15 cu. ft. instead of some other quantity? The Committee wrestled with that subject for a long time and was very much inclined to put in a higher requirement. It for a long time dealt with the subject of 20 cu. ft. per minute, but, finally considering that it seemed necessary to come down to a cubic content requirement of 80 cu. ft. of space per occupant, and realizing that, with 15 cu. ft. per minute, an air change of about eleven times an hour is provided on the basis of a minimum content requirement of 80

cu. ft., and a minimum of 4⅓ sq. ft. of floor area as a net seating space, felt that it was hardly authorized to put the requirement at more than 15 cu. ft. per minute per occupant. The Folk Ordinance, now being considered in New York City, is based on 500 cu. ft. per hour. Our requirement calls for 900 cu. ft. per hour, or 80 per cent. more than the proposed New York code. Fifteen cubic feet per minute per occupant, under average conditions of cubic content in motion picture show places, is about the amount of air that can be supplied without uncomfortable drafts, and, if well distributed and diffused, as will be necessary to meet the temperature requirement, called for by Section 4, seems to be fair to require by law as a minimum under the conditions stated.

Answering the second question, I would say the Secretary of the National Board of Censorship of Motion Pictures stated that he considered 15 cu. ft. per minute rather high, and explained that he had discussed the matter with some of the physicians referred to, and that, after talking with Dr. Gulick as well, 500 cu. ft. per hour per occupant was decided upon as a requirement for the new ordinance. As already stated, our requirement of 900 cu. ft. per hour is reasonably practical to secure, and we believe that we should stand for not less than this quantity.

The next question, as asked by Professor Kent, is fairly well covered by the explanation just made. The grouping of a large number of people in small spaces, such as we necessarily have to deal with in motion picture show places where the cubic contents per occupant in many cases would reach the minimum of 80 cu. ft. (many cases at the present time going much below this figure), compels us to come down to a minimum requirement of 15 cu. ft. per minute per occupant, in order to avoid undesirable drafts and be practical under the conditions.

The Committee discussed the point suggested by Mr. Baldwin, and is of the opinion that under Section 3 the owner of a motion picture show place would, of course, be compelled to put in apparatus capable of supplying 15 cu. ft. of air per minute per occupant, on the basis of a full audience, but it seemed to the Committee hardly fair to make a requirement that this total quantity of air should be supplied at all times on the basis of a total seating capacity when during certain hours of the day the number of persons in the audience might be small.

The suggestion of Mr. Miller is covered partly in the answer to Mr. Baldwin. The cubic contents per occupant in motion picture show places varies so widely that a requirement based on the number of changes of air per hour would bring a very undesirable result, as it would bring the least amount of air to the crowded places with small cubic contents and a correspondingly large amount of air where the space conditions per occupant are more liberal. If a number of changes were required it would be necessary to make a schedule varying with the cubic contents per occupant.

Professor Kent: I would like these statements to be incorporated in the report. There is no objection, of course, to the Committee fixing minimum values for that heading and so I think, instead of at least 15 cu. ft. of air per minute per person, I would like to have it stated in the main body of the report why it is that the Committee puts that figure down, saying that some people want 10 cu. ft., others 15 cu. ft., and others 20 cu. ft., and the schools require 30 cu. ft., and that the figure of 15 is a compromise between what the Committee thinks it ought to be and what can be secured.

Mr. Chapman: I refer Prof. Kent to the paragraph of general suggestions covering that point, as follows: It should be especially noted that the foregoing regulations call for a *minimum* of all requirements as compulsory, and that it should be the aim of the Administrative Department having enforcement of the Regulations in charge, to encourage motion picture show place owners and managers to provide as comprehensive, liberal, and high-class equipment as possible, with a view to catering to the comfort and health of the patrons, and thus add to the popularity of the show place as compared with others which may have barely come within the legal requirements.

Vice-President Hale: Is there any discussion on this paragraph? Is there no question as to the temperature? No recommendation to be made to the Council? If not, we will go ahead. Go on to the next paragraph.

Mr. Chapman: I would just like to make one remark about the matter of temperature requirement. It was the aim of the Committee, in putting this in the way it did, to cover a considerable requirement beyond mere temperature. It will prob-

ably be noted that, if the motion picture show place lives up to the requirement of 62 deg. to 70 deg. at the breathing line, it will have really to ventilate that place and get good air distribution. A requirement of temperature at the breathing line is readily noted as to whether the owner is living up to it or not. If the latter part of this requirement of Section 4, namely, "the temperature, distribution, and diffusion of the supplied outdoor air shall be such as to maintain the temperature requirements without uncomfortable drafts", is lived up to, it will insure reasonably good protection and will bring fair ventilation results.

Mr. Miller asked if the National Board of Fire Underwriters permits more than one opening in the booth.

Mr. Chapman stated that this matter had not been taken up with the Underwriters, but that the Committee had proceeded as a result of investigating what is being done in other localities, in Massachusetts, for example, where they use a number of vent openings at the bottom of the booth, as well as a vent connection at the top of booth, and in some cases a fresh-air connection to the bottom of the booth from out of doors.

Vice-President Hale: **Are there any other points, Mr. Chapman**, in the report, which should be called attention to at this time? Does not this cover all the points?

Mr. Chapman: This covers all the points that are deliberately suggested as minimum ventilation standards. The general clauses included in the report are considered by the Committee to be important, and are intended to be suggestive and helpful to persons and committees who are considering incorporating ventilation requirements in any general law regulating motion picture show places. Our idea was to go a little beyond the bare requirements of the report, with the idea that, if the report as presented were used, it would give the maximum of suggestive help. The Committee felt that the suggested minimum ventilation standards are really largely explained by the general clauses, and the general clauses, in our mind, are extremely important. The administrative feature is especially a very vital one, as demonstrated to the Committee in consulting with different persons who have had experience.

CCCXIII.

PRELIMINARY REPORT OF THE COMMITTEE ON LEGISLATION FOR COMPULSORY VENTILATION.

Your committee has had under advisement this year several drafts of a model law, but so far has not succeeded in putting it in such shape as to be wholly acceptable to the members of the committee. Each draft excepting the last one, which is here presented, comprehended a two-part bill, i. e., the first part including schools, auditoriums, hospitals, theaters, moving picture shows and other meeting places for mental, physical and social improvement and recreation; and the second including factories, mercantile establishments, mills and workshops. Of the two parts above mentioned the first presents an easier solution and the chairman here submits only that part with this report for your consideration, in the hope that some discussion may be given the subject to guide future committees in this work.

The chief difficulty in preparing such a work is the unsolved problem of "what constitutes good ventilation?" The old standards have been questioned and entirely discarded by many, but as yet no new ones are formulated to take their places. In this unsettled condition there should be a thorough discussion before the committee report can be said to represent the views of the society.

APPEARANCE OF RADICAL ARTICLES

Some technical articles appearing within the last year or two have made statements that are extremely radical, to say the least, when analyzed with calmness and good judgment. Many of these extremely partisan statements will later be found to be ill-advised, but the agitation proves conclusively that the subject is being studied more than ever before.

Prominent men of science are conscientiously giving time and energy to find a solution that may be generally adopted.

All honor to such men. Great care should be exercised, however, not to become so sensational and vitriolic in public denunciation of existing conditions as to forfeit the applause of thinking men, as was true of an article entitled "The Vicious Quantitative Standard of Ventilation," which came out in one of our prominent engineering journals bearing a photograph of the author and a half-page cartoon, the latter more fitted to adorn the front page of the *Police Gazette* than to elaborate what was supposed to be a serious article for the betterment of mankind, by one who claims to be an engineer.

Again, it is unwise to make sweeping conclusions as to the permanent effects upon human kind from a few short tests of a few hours' duration, as for example the following, which is quoted verbatim from one of our American journals:

"These experiments prove conclusively that through the metabolic assimilation of man no gaseous excretions of a toxic character and capable of causing health-interfering effects observed in crowded rooms, are thrown into the atmosphere. On the other hand, all the experiments indubitably indicate that the cause of such interference with health is to be traced to the thermal conditions of the environment and to the heat accumulation conditioned by this environment."

Such a statement is justifiable only after years (instead of days) of careful investigation. No one will doubt that the experiments leading up to this conclusion showed improved temporary comfort and stimulating effect by certain degrees of air movement, temperature and humidity, but how about the permanent effect?

Suppose a number of persons were being experimented upon and some of these were unfortunate enough to be afflicted with diseased lungs or skin. Would the health of the other occupants be permanently affected if obliged to breathe this air indefinitely? Suppose we assume that all the persons were in good health when the experiment began, could they maintain this good health permanently in an atmosphere where the by-products of combustion are continually increasing and the health-giving qualities of the air are continually decreasing? Granting that CO_2 is not poisonous, how much of an increase of CO_2 may be permitted in the air that is to be used continuously?

Granting that we can exist without *temporary* discomfort in

an atmosphere having much less than 21 per cent. oxygen, what will be the *permanent* effect?

These are some of the questions that need to be seriously considered before we can consistently disregard, as some have advised, that time-honored axiom, "pure outdoor air and plenty of it." This society stands for scientific progress, and every member will welcome a thorough discussion of this most important subject.

PROGRESS IN WORK

In addition to the efforts of your committee to formulate a typical law, the work in the field is not at a standstill. In at least two states there are hopes of obtaining compulsory ventilation laws. In Nebraska your representatives are working with a committee from the Nebraska State Medical Society and expect to submit a ventilation bill to the Legislature which is now in session. In Tennessee our member, Mr. Harwell Allen, reports that he hopes to be able to submit a bill to the Legislature of that state. We trust that both of these endeavors may be fruitful.

WORK IN CHICAGO

In Chicago Dr. E. Vernon Hill has been appointed Chief Ventilation Inspector, with assurance of such assistance as will be necessary to see that the ventilation ordinances are carried into effect. This is certainly a step in the right direction. In addition, the Chicago Ventilation Commission has been reorganized with a few new members, including a member of the American Institute of Architects and a member of the Chicago Architects' Business Association. This commission will hold meetings throughout the coming year every two weeks. We hope this commission will continue the investigations with the experimental room in the Chicago Normal School, and be able to report some conclusive results at the end of the year.

CO-OPERATION OF MEMBERS REQUESTED

In concluding this report the committee, through the chairman, would urgently request all members of the society who have any knowledge of the working-out of any of these laws

to report their views as critical suggestions to the chairman of the committee for future guidance.

PROPOSED SPECIMEN VENTILATION LAW

General.—Whereas, one of the fundamental principles of this government is to guard the health of its citizens, and whereas, it is considered absolutely necessary to health that buildings used for school purposes, auditoriums, hospitals or sanitariums, theaters, moving picture shows and other meeting places for mental, physical and social improvement and recreation, hereafter to be erected by any municipal board, public or private corporation or private citizens, shall be properly heated and ventilated; therefore:

Section 1. Be it enacted by the General Assembly of the State of ——— that the State Board of Building Inspectors (or other organization appointed or elected to fulfill such duties) shall not approve any plans for the erection of any building as above stated, whether public or private, containing a room or rooms to be used as meeting places, study rooms, rest rooms, sick rooms or wards, laboratories, workshops, corridors, cloak rooms, toilet rooms, etc., unless the plans are in accordance with the following provisions covering such work:

HEATING

Section 2. Every office, assembly hall, recitation room, rest room, sick room or ward, corridor, cloak room, work room and toilet room, in every building used for school, health or other meeting purposes, where one or more persons are engaged in study, research, entertainment or rest, shall have provision for securing and maintaining uniform temperatures in all parts of said rooms, and such temperatures shall be maintained at all times when said rooms or apartments are occupied.

Section 3. Temperatures shall be considered satisfactory between 65 and 70 deg. F. within the offices, assembly halls, recitation rooms, rest rooms and sick rooms; 60 to 65 deg. for gymnasiums, and 60 to 70 deg. for all corridors, cloak rooms, work rooms and toilet rooms. No room shall be considered satisfactorily heated that has a variation of temperature in different parts of the room of more than 5 deg. F.

VENTILATION.

Section 4. Every office, assembly hall, recitation room, rest room, sick room or ward, corridor, cloak room, work room and toilet room, in every building used for school, health or other meeting purposes, where one or more persons are engaged in study, research, entertainment or rest, shall have provision for securing and maintaining proper and sufficient ventilation, and such ventilation shall be maintained during such hours as rooms or apartments are occupied.

Section 5. In all such buildings, located where the ventilating air may be made impure by dust from the streets or from other impurities held in mechanical suspension, approved filters or air washers shall be installed and said filters or air washers shall be kept in full operation during such hours as rooms or apartments are occupied.

Section 6. In all buildings ventilated by mechanical means, there shall be installed humidity appliances capable of controlling the relative humidity of the ventilating air within a maximum fluctuation of 10 per cent.; the range of humidity to be between 50 and 70 per cent.

Section 7. Any room or apartment mentioned above shall not be deemed sufficiently ventilated except as follows:

First.—At least 200 cu. ft. of air space, or 15 sq. ft. of floor space shall be provided for each and every person occupied therein.

Second.—Pure air shall be supplied in the amounts as stated in this section.

For sick rooms, contagious diseases, hospitals, 3,600 cu. ft. per hour per person; for sick rooms, not contagious diseases, hospitals, 2,500 cu. ft. per hour per person; for auditoriums, schools, etc., 1,800 cu. ft. per hour per person; for each cubic foot of gas burned, 1,000 cu. ft. per hour.

Third.—Any room or apartment having at least 1,500 cu. ft. of air space for each and every person within the room or apartment and having outside windows and doors whose total net area is at least one-eighth of the total floor area, shall not be required to have artificial means of ventilation, excepting where the air is made impure by fires, gas jets, drains, etc., in which case special provision shall be made against these impurities; but all such

rooms shall be properly aired before beginning work for the day and during meal hours.

Fourth.—Any room or apartment having less than 1,500 cu. ft. and more than 500 cu. ft. of air space for each and every person within the room or apartment, and having outside windows and doors whose total area is at least one-eighth of the floor area, shall be provided with artificial means of ventilation which shall be in continuous operation during the period of occupancy when the outside temperature requires the windows to be kept closed, and which shall supply during each hour of occupancy the amount of air as stated under this section.

Fifth.—No part of the fresh air supply required for any room or rooms in any building shall be taken from any cellar or basement or from any other source than a direct withdrawal from the outside air.

Sixth.—The terms used in this section shall be interpreted thus: The ***air space*** required for each person is the total interior volume of the room expressed in cubic feet, without any deductions for equipment contained therein, divided by the number of persons employed therein. ***Outside windows and doors*** are those connecting directly with the outside air; the ***window and door area*** is the total net area of the windows and doors of all openings in outside walls, and the ***floor area*** is the total floor area of each room.

Section 8. Air velocities used in heating and ventilating systems for buildings as above stated shall be not more than 400 ft. per minute at the register and 700 ft. per minute in the vertical stacks or ducts. Where mechanical air washers are used the velocity of the air flowing through the air washer shall not exceed 400 ft. per minute.

Section 9. Responsibility of providing for and maintaining said heating and ventilation shall rest with the ———.

Section 10. If a room or apartment as above stated is not provided with proper and sufficient means for heating and ventilating, the commissioner or other person in charge of such responsibility shall issue or cause to be issued to the ——— or to his representative an order requiring such heating or ventilating apparatus to be installed within a specified time, also requiring that such apparatus be maintained in operation in accordance with these aforesaid provisions.

DISCUSSION.

Chairman Hale: Gentlemen, you have heard the report. Are there any remarks you wish to make?

Mr. Lewis: In connection with that report I suggest some thought concerning the proposed code of the State of Ohio. This code goes so far beyond anything I have seen in compulsory legislation that it should be carefully considered. Here are a few of the provisions:

"No fresh air must be admitted through a screen having not less than 900 meshes per square inch, or through an air washer. The maximum permissible velocities of air are fixed by law throughout all parts of the whole ventilating system. The maximum speed of the fan is fixed by law. The location of the registers must be in a certain location on the side wall. The registers must be at a certain height from the floor, under the law, and cannot go anywhere else. The amount of direct radiation and the amount of indirect radiation is fixed by law in proportion to the size or contents of a room, and cannot be less than called for. The thickness of walls in masonry flues is definitely fixed. All steam pipes in the basement must be covered. Perhaps that is a good thing, but I think it is going too far. Not more than two radiators may be controlled by each thermostat. That is a fine requirement for the temperature regulation people, because many times it is perfectly possible and right to control a dozen radiators by one thermostat.

These are just a few of the rather arbitrary requirements that are in the Ohio code, and I think there is plenty of room for discussion in it if we have time during this session. It ought to be taken up and investigated, I think, by the Committee on Compulsory Legislation. I was only able to get a copy of it this week.

Professor Kent: I suggest that the report be printed for distribution to the members as early as possible and that a letter of transmittal be sent the members, asking them to get all the information they can on the subject from all the authorities on heating and ventilation, that other industries be asked to contribute, and that the authorities in different states be asked to express their opinion on it, for discussion only, and that it be made a special subject for discussion at the summer meeting. I

think we want to get all the information together possible on the kind of legislation that we should have, and it would be well to have such information compared with this Ohio code and see if we can get our code to be a better one than any yet proposed. I do not think it is policy for this society to promulgate or frame a law unless it is better than any now in use, and we ought to have the advantage of critically examining all that are in existence, so that when we finally print our code it will be accepted by authorities generally as being about what is right.

Chairman Hale: I believe the thought expressed in the committee report was in that direction, although probably not as complete as you have stated it.

Mr. Weinshank: The reason that the report came to the commission as it did is because Professor Hoffman, with whom I have spent considerable time in preparing this paper and who, you will notice, wants the members present to discuss the matter, and, as he thought he could not be here, asked me to state that if this report interested the Society it would be better to refer it back to him with comments and suggestions, and he, with my assistance, if you give me an opportunity, will get together again, and shape it up in the form of a paper for the summer meeting. The members will then have an opportunity to criticize and make suggestions that will develop a model law that we hope will be a credit to the Society.

Mr. Haslett: Mr. Chairman, several years ago I was invited to appear before a committee which had under consideration a school law, and previous to attending the meeting I wrote to the American Society of Heating and Ventilating Engineers —that was before I became a member—asking what they had to suggest in regard to a proper law governing heating and ventilating of public buildings. I received a very courteous reply that the management of this Society had under consideration at that time a uniform bill, a bill that would be proper to present to the different legislatures when these questions came up; and from time to time I have been looking for some draft of a bill of that kind; and to-day I find that we are no nearer getting at a result than we were several years ago when I first wrote to this association for information. It occurred to me when the report of the Compulsory Ventilation Committee was read, and they suggested a number of places where they were active, that

they should consider the State of Delaware. The state legislature is in session at this time, and at the last legislature a committee of five was appointed to draft a law covering the construction of public school buildings. I have had some communication with this committee, and I referred them to the Secretary of this Association a year or two ago, and it was then said that a bill would doubtless be agreed upon in the very near future. I ask the committee what if anything is being done at this time, or if they know anything about the condition in Delaware? Now is the time to strike. The time is ripe for the committee to take this up with the special committee that was appointed by the Governor of Delaware. There are a number of school buildings in process of erection there now, and, if we expect to accomplish all the good we can, we had better get busy and help the cause in Delaware.

Chairman Hale: The attempt will be made to get the information you ask for, Mr. Haslett, and the recommendation will be made to the committee to make more rapid progress if they can toward getting this report completed.

Mr. Lewis: This is an instance that I meant to call attention to when I was criticizing the Ohio code. It seems to me, in view of the radical improvements that we are learning to make in the ventilating and heating of buildings, that it is very undesirable for this Society to sanction any compulsory ventilation law which states how anything shall be done. We should have a law which should call for results, leaving it to the invention and ability of the heating and ventilating engineers to produce that result, not to do as the Ohio code does, when it attempts to specify how the work should be done.

Chairman Hale: Are there any further remarks on this subject? Is it the wish of the members here that this report be accepted and placed on record?

Mr. Haslett: Mr. Chairman, I move the report be accepted and taken up Thursday at ten o'clock for special discussion, if that will not interfere with the program. I think it should be thoroughly discussed by this meeting before we go on record as favoring it.

President Hale: The report of the Committee on Compulsory Legislation was deferred from Tuesday until such time as the same could be printed. Galley proofs of this report are now

in your possession. It came up for a reading this morning, and at your wish I put it off until this afternoon, in order that Mr. Haslett might have an opportunity of starting a discussion, as he was the gentleman who made the suggestion, that the members have an opportunity to look into the subject before it was passed upon.

Mr. Haslett: Mr. President, I received this report a little while ago and glanced at it very casually. I will assume, however, that the members present have copies of the proposed act, and that they have thoroughly studied it. I am not in a position to start the discussion, or to discuss it very intelligently. Some things about the report I do not approve of. The question, as I understand it, is, shall it be the consensus of opinion that this report be amended?

President Hale: What disposition is to be made of the report? It was not passed upon, but is up for consideration.

Mr. Haslett: Then I move that the report of the committee be received and referred to the Board of Managers and printed.

Professor Kent: I would like to add to that, that it be distributed to the membership and made a subject for discussion at the summer meeting.

Mr. Whitten: As a member of the committee I have had some correspondence with the chairman. A tentative draft of the report was presented to me last summer, very much more voluminous than this. In the correspondence that followed the idea was that this is simply a tentative report, being put in shape that it would be adaptable for the various states, and to the different climatic conditions. I think that this report is intended by the chairman only as something which has been put up in order to provoke discussion and to bring all the light on the subject that may be opened up.

Mr. Lewis: As a member of that committee I think the intention of the Society in giving time to have these slips printed was that the matter be given full discussion on the floor. In that light I think there is a question whether we should propose a bill which embodies, as this tentative one does, a method of enforcement. Perhaps it is all right to suggest a method, but in almost every state the method of enforcement would have to be different, would have to be worked out by local legal talent. I think it is not our province to attempt to cover that part of any

bill. What our business should be is to set the technical requirements from the standpoint of heating and ventilation that such a bill should embody, and that is as far as a Society should attempt to go.

President Hale: Mr. Haslett made a motion, and it was seconded by Professor Kent, that the committee report be received and placed on record, printed and distributed among the members.

Mr. Barron: I make a suggestion to the President that the Secretary read the proposed bill by sections, if there is time for it, and in that way you could get a discussion on the paper.

President Hale: Considering the suggestion made by Mr. Barron, which is a good one, the Chair rules that we will take five minutes for each of the four numbered paragraphs, and discuss them within this time. The Secretary will kindly read the first paragraph.

Mr. Haslett: There are two things in that clause that should be taken out. I do not know whether this committee took into consideration odors or not; but I happen to know, or think I know, that in some diseases 70 degrees is considered, under certain conditions in a sickroom, hardly sufficient. I would like that to be taken up. And, in the next place, 5 degrees in any part of the room, should be modified, because if you expect to limit that to 5 degrees between the ceiling and the floor you are going too far. In the same plane it would be all right.

Mr. Quay: It might be all right in the same plane if we had closed windows, but with open windows and the velocity changing all the way from ten to sixty miles an hour, and temperature changing very rapidly, I think the question of how the windows are to be taken care of on account of leakage would have to be considered when you consider the question of variation in temperature.

Professor Kent: I also object to that statement of 5 degrees difference in temperature. In this room, for instance, it makes no difference how much hotter the air is above us, which we do not have to breathe and do not have to feel. I think that variation of 5 degrees should be limited to certain places, say the breathing line and below, to allow the higher portions of the room to be hotter if need be.

Mr. Armstrong: I should have that on any horizontal plane.

I do not think you could readily determine the breathing line. The breathing line for a child would be three feet, and in other cases it would be six feet six inches. In my case it would be six feet two inches. Another thing, the question of the sick room: In a case of croup, I believe the doctors like to have the temperature as high as 80 degrees. It would be rather difficult to set a limit to the temperature of a sick room.

Professor Kent: I am glad they brought up the question of temperature. In some cases they cannot have over 60 degrees, in some they must have as high as 80. If you are going to make a difference of temperature of only 5, I think it is a mistake to include that variation of temperature unless you confine the question of area and velocity to leakage around the windows.

Mr. Whitten: I think it is a mistake to inject this sick room matter into this paragraph at all. There are offices, assembly halls, recitation rooms and rest rooms, in which the ranges of temperature which are proper and beneficial are comparatively small; whereas in sick rooms it may be very, very high or low, and such provisions should be eliminated from this paragraph.

Mr. Armstrong: I think that sick rooms should be omitted. I think there ought to be a general clause exempting sick rooms from any of these provisions, for the doctors will cut such out anyway.

Mr. Haslett: There is no provision later on in the bill prescribing what good ventilation is.

Secretary Macon: "Section 6. In all buildings ventilated by mechanical means there shall be installed humidity appliances capable of controlling the relative humidity of the ventilating air within a maximum fluctuation of 10 per cent.; the range of humidity to be between 50 and 70 per cent."

Professor Kent: I find the same thing referred to in the *Metal Worker,* which has just been published, and also find in the report of the Committee on Schoolroom Ventilation, presented by Mr. Frank Irving Cooper, these words: "To secure the greatest comfort the relative humidity should not exceed 55 per cent.; somewhere between 45 and 50 per cent. is probably the best range." Now, if we accept that as being correct, why should we recommend legislation providing 55 per cent.? I think this clause, too, should be stricken out or changed.

Mr. Whitten: In regard to humidity there are many indus-

tries where humidity is commercially necessary, which fact is considered in all buildings ventilated by mechanical means. I think that is a matter that we want to go very slow on. If it is occupied for purposes of study or observation, it is one thing. If we are manufacturing woolen cloth, it is another thing; hence it seems to me that the humidity requirements should be more specifically stated to accord with the purpose for which the buildings are used. I would say there is no question in my mind but what 70 per cent. for ordinary conditions is very much too high.

Mr. Hinkle: This, I believe, is another subject that was put up to the physicians last year, and I am still listening for their decision.

Mr. McCann: In regard to the matter of humidity for average conditions, cold weather, this requirement as to relative humidity could not be complied with unless double sash were used, and, of course, we have not the right to say that double sash must be used. It seems to me, therefore, that the committee should change this to require a relative humidity varying with and depending on the outdoor temperature, and also applying specifically to the trade for the purposes for which the premises are to be used.

Secretary Macon: Reads "Section 7. Any room or apartment mentioned above shall not be deemed sufficiently ventilated except as follows:

"First. At least 200 cubic feet of air space, or 15 square feet of floor space, shall be provided for each and every person occupied therein."

Professor Kent: If that word, "or," read "and," I think it might be made, "at least 200 cubic feet of air space and 15 square feet of floor space shall be provided for each and every person occupied therein." Leaving the word "or" stand there, then, I think anybody could put in 15 square feet of floor space and have a room 8 feet high.

President Hale: The point is well taken. Is there any further discussion of that particular point? If not, the second paragraph will be read.

Secretary Macon: Reads "Pure air shall be supplied in the amounts as stated in this section.

"For sick rooms, contagious diseases, hospitals, 3,600 cubic

feet per hour per person; for sick rooms, not contagious diseases, hospitals, 2,500 cubic feet per hour per person; for auditoriums, schools, etc., 1,800 cubic feet per hour per person; for each cubic foot of gas burned, 1,000 cubic feet per hour per person."

Professor Kent: Another committee has reported that we should have 900 cubic feet of air for moving picture shows, and this says an auditorium should have 1,800 cubic feet. There is a great discrepancy there.

Mr. Chapman: I think it was an error to require 1,800 cubic feet for many auditoriums.

Professor Kent: This is to be referred back to the committee. I wish they would also consider whether modifications in these figures should not be made in case of upward ventilation. I think it is generally considered, if we had upward ventilation, we might get along with a smaller supply of air. I do not know whether it is so, but it is the opinion of a good many people that it is.

Mr. Armstrong: I recommend that all of the succeeding paragraphs be given prayerful consideration by the committee. We are getting onto dangerous ground when we attempt to prescribe how much air a man ought to have or the condition of it. I am satisfied no one knows at the present time. It is only recently that we have discovered that there are a lot of gases in the air that we did not know existed, such as argon, kripton, zenon, neon, and helium. We have been breathing air so long that we considered we knew all about it, yet, as a matter of fact, we know next to nothing. Is there not some property motion, excitant, or some other thing in the air we breathe that is, after all, the vital thing, and we should make a careful study to discern it? Is there not some condition that stimulates our appetite for oxygen, just as there are chemicals that stimulate our appetite for food?

May it not also be that there is something as yet not defined, that makes the air acceptable to our lungs? We have all experienced the sensation when on a mountain or at the seashore, while taking in a full breath, that caused us to exclaim, "Oh! how refreshing!" An ordinary chemical analysis of that air, when compared with the air from the slums, would show no vast difference.

By actual experiment, if the purest air were taken from the top of a mountain, and introduced into a cellar, and we were compelled to breathe it, we would feel the sensation known as "oppressive," and the air would speedily become unpalatable.

Just what is it that makes the difference? To ascertain this is the work this Society has before it. When we have discovered that, the whole science of ventilation will be a more simple problem.

Let us get together and see what this mysterious agent is.

President Hale: Are there any further remarks that the members wish to make in connection with this, any part or as a whole? Personally the chair wishes to recommend to the gentleman making the motion that he reconsider it, in view of the discussion that has been in evidence, showing that there are many points which the members do not agree upon. The committee make the recommendation to the Society; this is the Society; and if we accept it there are members here who have shown that they do not believe that it is correct, and we will probably have to take a vote upon it.

Referred back to committee for report at semiannual meeting.

CCCXIV.

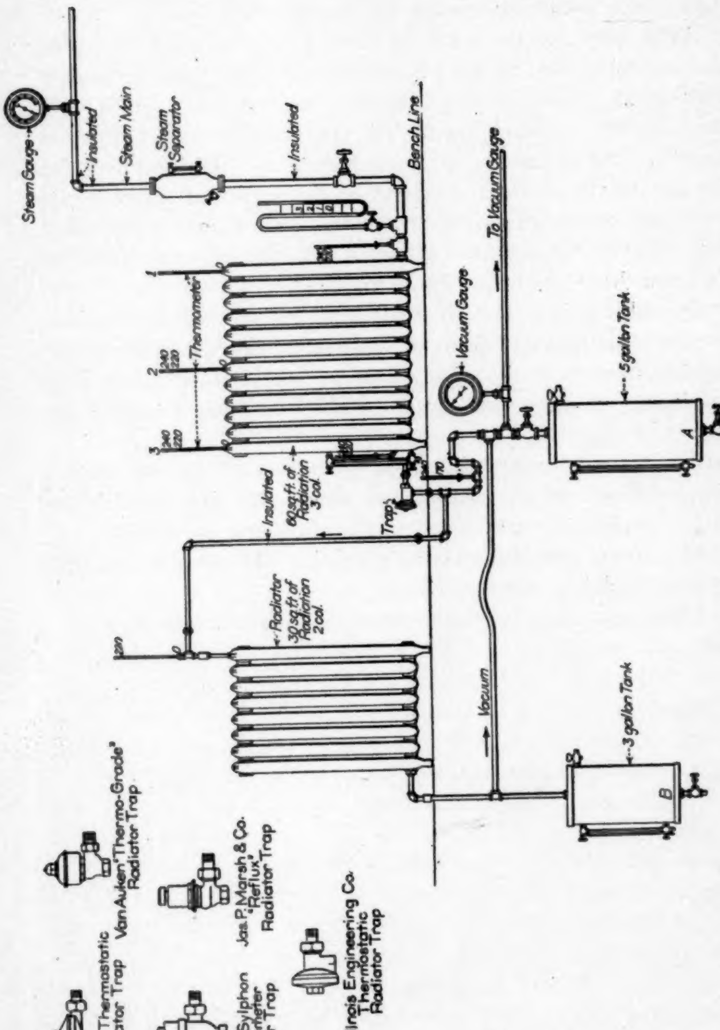
TEST OF RADIATOR STEAM TRAPS, ENGINEERING DEPARTMENT, STATE OF CALIFORNIA.

E. D. GRIFFITHS.

REPORT OF TESTS OF RADIATOR STEAM TRAPS.

The testing apparatus, set up as illustrated in the diagram plate, consists of a radiator of sixty square feet surface, provided with thermometers in the top of three of the sections and at the base in the inlet and outlet ends, so that any tendency to air bind can be detected. It is also provided with a gauge glass on the side of the radiator so as to detect any tendency to collect water. A steam separator is placed in the steam line on the inlet side of the radiator to remove any water and insure practically dry steam entering the radiator; a mercury manometer is also connected to the steam pipe near the radiator on the intake end, by which the pressure may be observed. The trap under test is placed at the outlet of the radiator and the discharge carried through a water seal, provided with thermometer as shown, into a collecting tank *A* below, from which it can be drawn off at pleasure. The vapor passed through the trap is carried up and over into an auxiliary radiator, also provided with a thermometer, where it is condensed and dropped into tank *B,* shown at the left of the cut. The system beyond the trap being tested is under vacuum, which is maintained by a steam driven pump. Tanks *A* and *B* are connected by a pipe having a hump in it, so that no condensed steam can pass from *B* to *A*. This arrangement would probably cause reëvaporation to occur in tank *A,* due to the drop in pressure, and this vapor would pass into tank *B,* since the temperature in *B* is much lower than that in *A*. The water drawn from tank *B* then represents the vapor passing through the trap under test, together with the reëvaporation in tank *A*.

The object of these traps is to pass all water and air with a



TEST APPARATUS.

minimum loss of steam. The results of the tests are recorded on data sheets, which exhibit the amount of steam loss.

After each run the water in tank *A* was weighed, this being the amount passed by the trap under test. The water in tank *B*, representing the steam lost through the trap and condensed in the auxiliary radiator plus the reëvaporation in tank *A*, was also weighed, the percentage of steam loss being calculated by dividing the weight of water in tank *B* by the weight of water in tank *A*. Any tendency to air bind is noted immediately by low readings of the thermometers at outlet, and numbers one (1), two (2) and three (3) at the top of radiator.

In making these tests there was no effort made to eliminate grease, scale and dirt from the apparatus, the object being only to determine how the different traps would work under these conditions, as they exist to some extent in all steam-heating systems.

For examinations made of the interior of the various traps at the conclusion of the tests it was found that grease, scale and dirt accumulated more or less on the valve and valve seats.

The more pronounced this condition the greater tendency toward clogging and steam loss.

These tests were confined entirely to thermostatic traps.

E. D. Griffiths,
Testing Engineer.

CCCXV.

REPORT OF TESTS OF RADIATOR STEAM TRAPS.

BY JAMES A. DONNELLY.

A test of radiator steam traps or return line vacuum system appliances was referred to the Committee on Tests at the Detroit meeting, for the purpose of formulating a standard method of testing these devices and system appliances. I would, therefore, submit the following suggestions for your consideration:

First.—The appliances should be tested upon several radiators at the same time, in order that a fair average may be secured.

Second.—They should be connected to the return line and vacuum pump in the ordinary manner, the total amount of surface in the return line to be about ten per cent. of the radiating surface under test.

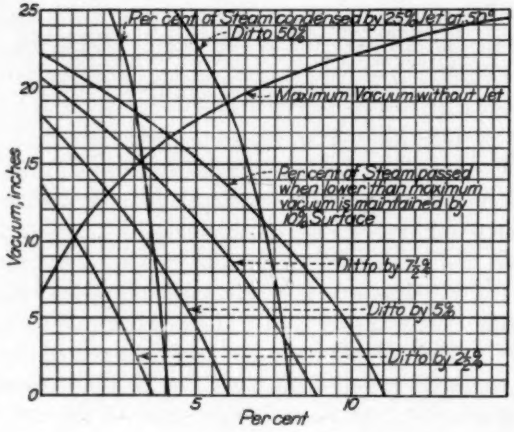
Third.—Several tests should be made with the pressure varying about as it might be expected to in ordinary operation, from atmospheric or slightly below, to about five pounds gauge.

Fourth.—The vacuum pump should be of such a size that when run at a normal piston speed it will have about the capacity ordinarily used—ten times the displacement of the water handled.

Fifth.—Records of the room temperature, the total condensation, the pressure and temperature at the inlet and outlet of the radiator, and the pressure and temperature in the return line should be kept.

The efficiency of different devices under test may then be observed by the total amount of condensation collected; by the temperature maintained at the outlet of the radiator, and by the degree of vacuum maintained upon the return line. Any tendency of the automatic valve to retain air or water in the radiator will immediately become apparent by the drop in temperature at the outlet of the radiator. Those devices that pass the least steam will maintain the lowest absolute pressure in the return pipe. If the temperature of the water and steam leaving the radiator is noted, the percentage of steam passed may easily be determined.

The most efficient devices will be the ones that maintain the highest temperature at the outlet of the radiator and at the same time maintain a satisfactorily low vacuum in the return main.



The accompanying chart shows the degree of vacuum which may be maintained with varying percentages of return surface (or perhaps more accurately speaking, radiating effect) also the per cent. of steam passed and condensed in the returns when a pressure higher than the maximum vacuum is maintained; as well as the percentage of steam condensed when jet water is used. These figures are based upon the assumption that the water of condensation is about ten degrees cooler than the steam from which it is condensed in cast iron radiators, as observed and reported by the Committee on Tests last winter.

Square feet of radiation in the returns necessary to cool the water of condensation or, inversely, the maximum degree of vacuum that can be carried without the use of jet water. The automatic valves are presumed to prevent the passage of steam and the water of condensation is figured at a temperature 10 degrees cooler than the steam from which it is made. Figured on a 100 sq. ft. radiator at 30 pounds of condensation per hour:

Vacuum	Temperature Steam	Temperature Condensed	Temperature Vacuum	Diff. x 30 lbs.	Divide by transmission per sq. foot	Sq. feet
10"...........	212	202	192.23	293.1	250	1.2
15"...........	212	202	179.03	689.1	218	3.16
20"...........	212	202	161.42	1,217.4	175	6.97
25"...........	212	202	133.77	2,046.9	110	18.6

Per cent. steam passed when less than the maximum degree of vacuum is maintained by ten per cent. of surface in the return piping.

Vacuum	B.t.u. from 10 sq. feet		Less B.t.u. from water	B.t.u. from the steam	Divide by 970 B.t.u. x 30 equals % steam
5"	2,780	(add)	30	2,810	9.65
10"	2,500		293.1	2,206.9	7.6
15"	2,180		689.1	1,490.9	5.12
20"	1,750		1,217.4	532.6	1.83
Ditto by Seven and One-half Per Cent.					
5"	2,085	(add)	30	2,115	7.27
10"	1,875		293.1	1,581.9	5.43
15"	1,635		689.1	945.9	3.25
Ditto by Five Per Cent.					
5"	1,390	(add)	30	1,420	4.9
10"	1,250		293.1	956.9	3.29
15"	1,090		689.1	400.9	1.38
Ditto by Two and One-half Per Cent.					
5"	695	(add)	30	725	2.49
10"	625		293.1	321.9	1.1

Vacuum	Temperature Vacuum	Minus 50 Eq. B.t.u.	B.t.u. by 7.5 Lbs.	Divide by 970 B.t.u. x 30 equals % steam
5"	202.92	152.92	1,146.9	3.94
10"	192.23	142.23	1,072	3.69
15"	179.03	129.03	967.7	3.38
20"	161.42	111.42	835.7	2.88
25"	133.77	83.77	628.3	2.17

DISCUSSION.

Professor Kent: I would ask Mr. Donnelly if that word in the first line should not be "on" the return line.

Mr. Donnelly: Some people call them steam traps, and some call them return line vacuum systems.

Professor Kent: I thought the whole system was called the return line vacuum system.

Mr. Donnelly: The practice varies so much that some people consider them merely devices, and the system really the creation of the man who puts the apparatus together.

Professor Kent: That is the trouble I find with this whole paper: technical terms are used that I do not understand. Is this the report of the committee or just your report?

President Hale: This is a report of Mr. Donnelly in addition to the committee's report, in reference to this matter that he has individually investigated.

Professor Kent: It may be all right, but it seems to me it is rather difficult to understand, for I do not comprehend all the statements. For instance, 25 per cent. jet on the blueprint. I do not exactly understand what a jet is.

Mr. Donnelly: A jet of water equal to 25 per cent. of the condensation from the heating system.

Professor Kent: Possibly it would be more intelligible if that was stated in the report. I suggest that before this report is finally distributed we should get suggestions from Professor Breckenridge, of Yale, and Professor Thompson, of the Bureau of Thermal Research at Buffalo, who are both capable of contributing data on this subject.

Mr. Barron: I would like to ask Mr. Donnelly, through you, if the substituting of an injector for the vacuum pump would make any difference in his deductions that he was putting out.

Mr. Donnelly: It would, very materially, because the water jet of the injector would probably condense considerable steam in the return line. If the water jet was taken from a tank and returned to the same tank by a centrifugal pump, as one device is constructed, and if consideration was given to the heat absorbed and radiated by the tank, or if the tank was covered, perhaps very little if any steam would be condensed. The test should preferably be made with a small piston pump; the idea being that it is preferable to make a test with an apparatus as generally used and not some special apparatus which is comparatively seldom or very infrequently used.

Mr. Quay: I do not assume that the committee's report is to be adopted.

President Hale: The committee's report has already been referred to the incoming Council. It has been accepted as a report and placed on file.

Mr. Quay: The reason I asked that question was that there are a great many questions in regard to the return line vacuum system that are not very fully understood, even by engineers who claim to be experienced in that line. So I think it would be well if the committee could be continued to make further investigation and further tests, and, as Professor Kent has suggested, to confer with other engineers who are making these tests. To show the necessity of this, last spring a number of vacuum heating companies estimated on their system for a prominent building in Chicago. Their return line valves or traps were submitted to an engineer to test them for approval, and briefly his statement was that the return line valve, to be satisfactory, must retain the water in the radiator until it cooled down to 160 or 165 degrees.

I think any vacuum heating engineer who understands his business would not agree with that conclusion, but he was the authority, for the time being, at least, and the valves were purchased on his report and recommendation.

I saw a test made last winter by another manufacturer, where they retained the water in the radiator down to 150 degrees, and the master mechanic said: "That is what I call a perfect valve." Having had the authority, I took him in hand and gave him a lesson in reference to the efficiency of a radiator when the water was removed, as it was condensed, compared with retaining or trying to retain the water in the radiator until it reached 150 degrees. These two cases (and there may be many others) show that there needs to be more investigation and more intelligent consideration of return line valves as affecting the efficiency of the heating system. You cannot retain the water in the radiators if the steam connection is made at the bottom until it gets down to 150 or 160 degrees. It will go back through the steam connection the same as in a one-pipe system. What happens to it depends on how that steam riser is dripped. I do not care to take any more time on this matter, but I think it would be well if the Council would retain the same committee or appoint another committee to make other investigations and tests along these lines.

CCCXVI.

REPORT OF THE COMMITTEE ON THE BEST WAY TO TAKE ANEMOMETER READINGS.

1. The opening shall be divided into equal rectangular areas, no side of which shall be over 10 inches long, excepting where this would require more than ten readings, in which case the opening shall be divided into twelve equal areas.

2. Readings are to be taken in every case at the center of every area.

3. Readings are to be one-half-minute duration, the anemometer being held at the register base or in the plane of the opening.

4. Where the diffusers are used, a total area is to be computed on the basis of the periphery of the diffuser.

5. The average of the readings are to be considered as the average velocity at the opening. Where negative velocities are found, they are to be deducted in arriving at the average velocity.

6. In computing volume, the net area of opening is to be taken, the volume to be considered as the product of the average velocity and the net area of the opening.

7. If the anemometer is held 2 inches from the register face, no deduction shall be made for the area occupied by the register mesh.

DISCUSSION ON THE REPORT.

Professor Kent: In connection with dividing the opening into rectangular areas, I do not think the committee has considered the possibility of the outlets being round. It is going to be a matter of some difficulty to divide a circle into twelve rectangular openings.

Mr. Haslett: I must confess that we did not take that into consideration. I do not think, however, that the members of your committee have seen a round register in recent years.

Mr. Whitten: Referring to the clause that readings are to be taken at the center of each area, the method adopted by the Massachusetts District Police, in making their measurements, has been to eliminate from the measured surface several inches of the lower portion of the inlet, as they have found practically no flow there whatever. If that were included, it would bring the center several inches, perhaps 6 inches, nearer this neutral area. In Massachusetts, in figuring the area of the inlet opening, an area 6 inches high of the full width of the opening, is deducted from the surface.

Mr. Lyle: That point was discussed by the committee in formulating this report, and we could not see the difference between deducting a certain amount of area from the bottom, or wherever there was no flow, and the method we have proposed of taking an average for the whole surface of the register. In fact, it seemed to us to be wrong to make any deductions, for the reason that there are times when we have a negative flow, due to an eddy current of air actually going into the register instead of going out. In such a case, if you consider the portion in which you have no outward flow as being wall surface, being blanked off, then your velocity is too high in the other portions.

Mr. Haslett: I do not think it would be possible to establish a rule of dead space, for the reason that it depends on the thickness of the wall and on the height of the register. If your register is high, and you have a thick wall, you are going to have a larger dead space every time, and very likely, the thicker the wall, the more chance there is for an inflow of air. To establish a dead space at the bottom of that register would be impossible, because you are likely to find dead spaces at other points than at the bottom. It depends upon the delivery of the air into the flue.

W. W. Macon: Referring to the measurements when diffusers are used, it seems to me that the type of diffuser might be such that the computed area would be very misleading. I think it would be better to leave off the diffuser until the flow of air is ascertained. In that case, the error would not be nearly so great as when the readings were taken with an odd-shaped diffuser.

Mr. Lewis: I would like to ask the committee if it took into consideration internal diffusers, such as those described by Mr. West two years ago (published in THE HEATING AND VENTILATING MAGAZINE for December, 1910). Mr. West designed an internal diffuser, which gave practically an even distribution of air all over the register face. That would seem to have some bearing on the dead air space in the register.

Professor Kent: I did not hear in the reading of the report any reasons for the adoption of these rules. No experiments are recorded and no information is given of the amount of error to be expected in the use of anemometers.

Mr. Armstrong: I think it will be a mistake to adopt the anemometer as an instrument for use in this connection. It has been thrown out by the Navy Department and Treasury Department and by the Institute of Mining Engineers.

Mr. Haslett: In our report the use of an anemometer is suggested simply as a method, because that is the instrument in ordinary use. There may be other ways just as good or better.

Mr. Lyle: We have a large number of comparative records obtained from Pitot tube and from anemometers. I believe we know the percentage of error with a Pitot tube very accurately. A comparison of the Pitot tube records with the anemometer records shows a wide variation. In our own work in determining whether or not our systems are properly balanced, that is, whether we were delivering to each individual room the proportion of air that was originally intended for it, we are using the Pitot tube and working on low pressures. We balance our systems that way. We find that we can do the work in about half the time as when using the anemometer. We have not found any customer, however, who would not take the anemometer reading as compared with that of the Pitot tube. You can, at least, see the anemometer wheel go round, but you cannot so easily see the operation of the Pitot tube.

Mr. Lewis: I think the committee has omitted one of the most serious questions that will arise in this connection. Suppose the building is supplied with cast iron registers? I know of many cases where they arbitrarily say, "We cannot take the net results through those holes." I move that in the report it be stated that, if the anemometer be held 2 inches away from the

register, no deduction need be made for the casting or webb of the register face.

Mr. Haslett: As I understand the suggestion, it is that if the anemometer is held two inches away from the register face, no deduction is to be made for the mesh.

Mr. W. J. Baldwin: It is my opinion that air issuing from the fret-work of a register cannot be measured accurately, either by anemometer or a Pitot tube, *the anemometer being held against the face of the register,* or the Pitot tube being used in the ordinary way to measure the pressure or by any kind of differentiation, for the reason that the pressures are too inconsiderable in the case of the tube, and in the matter of the anemometer, close against the face of the register, it gives results in excess of the truth, and when allowances are made they are guesswork. Guesswork goes with the use of the anemometer in almost any way it can be used.

Its calibration is guesswork largely, and the user has no convenient method of proving the accuracy of the instrument or of the expert; and a fall or the striking of one's fingers against the revolving vanes will upset the whole matter of adjustment.

In schools, etc., it is necessary to tell with some degree of accuracy the amount of air that will pass the registers. In such cases there is a mandatory law in many States, and it is often the duty of an inspector of the Board of Education to make reports, and these reports should have some accuracy. What is he to do, or what is the engineer to do, when he wishes to know if the ventilating apparatus approximates his expectations?

After a great many years' use of the anemometer I have come to the conclusions expressed in my opening sentence, that we cannot accurately measure air as it issues from the fret-work of a register, and that even our approximations may be a long way from the truth.

If we analyze the subject a little, and place the anemometer against the register face, as recommended, what happens?

A contracted current of air passing through a hole in the fretwork or grille strikes the anemometer wheel, and we get a record of the maximum velocity, or nearly so, and this maximum velocity is not effective over the entire area of the orifice, but over a restricted area of it, near its center, and this is modified unfavorably as soon as the orifice departs from the circular. The

passage through a square hole is not as favorable as through a round hole, and, when we come to the scroll-work, we are at a loss even to approximate the value.

Of course, we may find the area of the bar, and compare it with the passage or hole in the ordinary square lattice register (such as we generally find in schools), but this does not mean that because the ratio of opening is 36 as against 28 for the rib or bar that we are justified in giving the sum of the openings a value of thirty-six sixty-fourths of the register face.

Perhaps we would be justified in treating each hole as a *vena-contracta,* and giving it a value of seven-tenths its measured area, and if we do we have a value of only twenty-five sixty-fourths of the total register face, that we can consider as the effective area of the openings: something over one-third, but considerably under one-half; while the apparent ratio of air space to metal is 9 to 7.

The deductions I have drawn may be disputed, but that only goes to show the inconsistency of measuring against the register face.

The man who takes the whole area of the register must have a tremendous error, and the man who takes one-half may then be too high, if the anemometer is against the register.

What are we to do?

Again, if we do not measure against the face of the register, or very near it, where will we measure?

Some think we should measure about 2 inches from the register face in the cast-iron square lattice type. Presumably the maximum effect is obtained on the anemometer at this distance, but, if this is so, 50% of the total register face is ample to consider. Q equals $\frac{V \times A}{2}$.

My own method has crystallized into the use of a heavy cardboard cone, placed over the register face, with the smaller end of the cone approximately one-third the total area of the register face for cast iron square lattice. Some judgment must be exercised in determining the area of the small end of the cone. The rough rule is to make it no greater than the area of the openings through the register, nor less than seven-tenths of this area, but not smaller. This keeps the velocities nearly constant as between passing the register and passing the end of the cone.

The cone has a taper of approximately 30 degrees, and the readings are made in the end of the cone; then Q equals V x A, with small corrections if they are known.

'Tis true the cone may add a little resistance to the passage of the air. This can be considered usually as negligible, and may be looked upon as a toleration that is always in favor of the quantity of air admitted to the room.

Mr. Haslett: I would say that we took into consideration the use of a hood or cornucopia, as suggested by Mr. Baldwin, and, while that may be a good method, we thought that in large buildings, where there are different sizes of registers, the equipment for testing a building would have to be rather extensive.

As for the resistance, someone has suggested that, if a 2-in. nozzle, for instance, were used to throw water across this room, and you should substitute a 1¾-in. nozzle, you would throw the water much farther.

However, the committee did not undertake to recommend what instrument should be used, only that if an anemometer were to be used, how it were best to use it.

Mr. Williams: Referring to paragraph 6, of the committee's report, regarding net area of register openings, can you deduct anything in the case of a wire mesh register, either round wire, or square, ¼-in., woven wire mesh? I have found that you get practically the same readings with the mesh and without.

Mr. Haslett: The point raised by Mr. Lewis need not cause the report to be changed. If the customer or inspector chooses to avail himself of the protection Mr. Lewis suggests, then no deduction should be made. If not, then it places the engineer in possession of some test data.

CCCXVII.

HEAT LOSSES BY TRANSMISSION THROUGH VARIOUS BUILDING MATERIALS.

L. A. HARDING.

This report on the transmission of building materials is most important. The data obtained is taken mainly from the tests conducted at the Armstrong Cork Company's testing plant at Pittsburgh, covering a period of about eight years and representing an expenditure of nearly $25,000. Perhaps only a few of you are acquainted with this plant. The refrigerating engineers know more about it, possibly, than the heating and ventilating engineers. The figures in this report you will, I think, find rather interesting in a general way; inasmuch as the tests were not run on small boxes, they were good-sized boxes tested with a strong current of air circulating both inside and outside the box with a temperature difference ranging anywhere from 50 to 70 degrees, which corresponds to heating conditions and many actual refrigerating installations. A concern manufacturing insulating material is placed in rather a different position from a concern manufacturing heating and ventilating apparatus, inasmuch as they are often required to make an absolute guarantee of holding the temperature of a room after the direct expansion or brine coils have been shut off to a stated number of degrees drop in temperature for a certain number of hours. It is therefore highly important that they have rather exact data on the heat transmission of the walls. The report covers a variety of insulating materials which are to be applied to walls, though not so many walls of straight building material as I would like to see reported upon. It contains brick, hollow tile, concrete, cork boards, hair felt, compressed wall board, and several other insulating materials. The other part of the report is the tests recently made at the Pennsylvania State College under practically the same conditions, with the addition that the

surface temperatures of the material were taken as well as the temperature of the air in contact with the surfaces. If one takes the temperatures of wall surfaces and arrives at the unit of transmission and then takes the temperature of the air in contact with this surface quite a difference is often found in the unit of transmission.

I wish to call attention to the fact that reported tests on insulation or on building materials are practically of no value to anyone unless the conditions of the tests have been stated. Many tests are run in still air, while some are run in a strong circulation of air. The transmission of one box, which was constructed of poplar wood, was 9.49 in still air, and with a fan in motion 11.56 and on the cork board box with still air it was 6.94, and with the fan running 9.91. So you can see the advisability of standardizing transmission tests as well as boiler tests.

Our President calls attention to the very accurate results as quoted by the German authorities. They are very accurate, possibly, if you knew all the details of the tests.

The method usually employed in determining the value of the unit transmission of any material has been to construct a comparatively small box of the material to be tested in which a known weight of ice is placed. The heat transmission being calculated from the weight and latent heat of the ice melted, with no circulation of the air other than that due to natural circulation. This method is not altogether satisfactory for several reasons, and in order to eliminate errors and to run such tests upon a sufficiently large scale that the results could be depended upon, the Armstrong Cork Company, of Pittsburgh, several years ago constructed a thermal testing plant for this particular purpose. The principal features of this plant have been incorporated in the design of the new thermal testing plant recently erected by the engineering experiment station attached to the Pennsylvania State College.

The plant, briefly, consists of a particularly well insulated room or calorimeter located in an isolated building. A box, having approximately 50 to 100 square feet of radiating surface, being built of the material to be tested, is suspended in the abovementioned room. Heat is introduced into the box by an electrical resistance coil, the room in which the box is located being refrigerated by brine coils. By this method any temperature

difference that will in practice occur either in refrigerating or heating may be artificially reproduced.

Absolutely uniform temperatures may be maintained for an indefinite period and the method of measuring the heat introduced is extremely accurate. The results that have been obtained by different engineers at the Pittsburgh plant on a variety of materials have in general checked and are believed by the writer to be the most accurate data that at present exists on the heat transmission of the materials thus far tested.

RESULTS OF HEAT TRANSMISSION TESTS.

Penna. State College, by Mr. Cannon.

Test.	Material.	Surface Temp. Dif.	B.t.u.	Air Temp. Dif.	B.t.u.	
1	White Pine (surfaced)	22.5	13.12	31.77	8.42	Laboratory, still air
2	White Pine (rough).	18.7	13.59	26.9	8.28	Laboratory, still air
3	White Oak (surfaced)	20.1	11.93	28.8	8.02	Laboratory, still air
4	Hemlock (surfaced).	19.3	22.61	31.4	10.10	Laboratory, still air
5	Hemlock (rough)...	22.6	14.3	34.1	8.30	Laboratory, still air
6	Poplar (A).........	26.8	16.91	47.8	9.49	Laboratory, still air
7	Poplar (B).........	29.7	15.90	40.8	11.56	Laboratory, fan running
8	Poplar (C)..........	20.9	19.83	33.3	12.43	Laboratory, box slowly revolving
9	Compound wall, brick and wood...	26.8	13.22	37.1	9.96	Laboratory, box slowly revolving
10	Brick.............	6	25.81	19.6	107.5	Laboratory, still air
11	Cork board........	......	......	55.54	6.94	Thermal plant, still air
12	Cork board........	......	......	63.7	9.91	Thermal plant, fan running

Note:—Transmission given in B. t. u. per degree difference in temperature, per 24 hours, per square feet, per one inch thickness.

The results of tests which follow were made quite recently at the Pennsylvania State College testing station. These figures are interesting inasmuch as two transmission figures are given for the majority of the tests—one based on surface temperature differences and the other based on air temperature differences, the former figures to be later used in calculating the transmission of compound walls from the unit transmission of the various materials composing the wall in question. A considerable increase in the transmission is noted when the air is in motion inside the test box.

Test (5) on rough hemlock is much higher than the other, but a second and third checking of the test did not appreciably reduce the transmission. Tests (6), (7), and (8) are calibra-

tions run on the test box. In test (6) the fan was not running, while in test (7) the fan was running, the air velocity being about 500 feet per minute. In test (8) the box was mounted on trunnions and rotated at about one-half revolution per minute by means of a pendulum and escapement. For all other laboratory tests the conditions were the same as in test (7). The two last tests are the results of the calibration of the cork board test box in the thermal plant, test (12) fan not running and test (13) fan running as stated above.

HEAT TRANSMISSION OF BUILDING CONSTRUCTION.

The amount of heat required to be supplied the interior of a building artificially warmed or to be extracted when the building is refrigerated depends largely upon the type of construction employed. The transfer of heat through building construction was perhaps first experimentally investigated on a large scale by the French physicist Peclet. The laws governing the transfer of heat which he stated have been the basis of practically all treatises that have since been written on this subject. The transfer of heat always takes place, or is said to flow or pass from a warmer to a colder body.

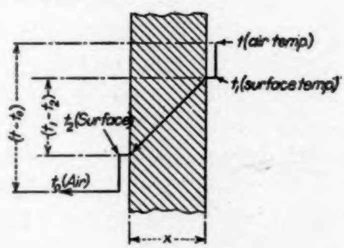


FIG. 1

Referring to Figure 1 showing a section of a homogeneous wall:

Let t_0 = mean temperature of outside air.
t = mean temperature of inside air.
t_1 = temperature of inside wall surface.
t_2 = temperature of outside wall surface.
x = thickness of the wall, inches.

Heat will be transferred to the inside wall surface and be emitted by the outside wall surface in two ways. The so-called *radiant* heat passes in a straight line from the surface of the warmer body through the air, without appreciably heating it, to the receiving colder surface. The air in direct contact with the warmer body will absorb heat and by the natural circulation transfer and give it up in turn to the wall surface. This kind of heat transfer is termed *convection*. The heat emission from the outer surface of the wall takes place in the reverse order. The transfer of heat from the inside to the outside wall surface through the material composing the wall is termed *conduction*.

RADIATION.

The quantity of heat which the surface of a material is capable of receiving or giving off to the surroundings by radiation is independent of the form, provided there are no re-entrant surfaces. It depends solely upon the nature of the surface and the temperature difference between the surface and the object to or from which radiation is taking place. The quantity of heat, M_R B. t. u. per square foot which a given outside wall surface will emit per hour may be stated as: $M_R = R\ (t_2 - t_0)$, in which R is the coefficient of radiation. It is here assumed that the temperature of the objects from or to which radiation takes place is at the same temperature as the surrounding air, which is approximately true.

The following table gives the results as obtained by Peclet:

TABLE I.

RADIATION COEFFICIENTS "R."

Values given are those determined by Peclet, expressed in B. t. u. per square foot per degree difference in temperature between the temperature of the surface and the objects from or to which radiation takes place.

Polished brass	.033
Tin	.053
Polished sheet iron	.092
Ordinary sheet iron	.567
Rusty sheet iron	.688
Cast iron, new	.649
Rusty cast iron	.688
Glass	.595
Fine sand	.741
Paper	.772
Building stone, plaster and wood	.737
Water	1.087

CONVECTION.

The quality of heat which may be transferred by convection or air contact from a warmer to a colder surface is independent of the form of the surface. It depends upon the temperature difference between the surface and the air in contact with it and the rapidity of the circulation of the air over the surface.

A natural circulation of air exists within an artificially heated room due to the tendency of the warmer and less dense air to rise to the ceiling while the air surrounding a building is often in rapid circulation. There are so many factors that affect the heat loss from the walls of a building by convection that it is quite impossible to give more than a rough approximate value for this coefficient.

The quality of heat (M_C) B. t. u. per square foot per hour which a surface will absorb or emit by convection may be stated as follows: $M_c = A\ (t—t_1)$ or $M_c = A\ (t_2—t_0)$, in which A is the coefficient of convection or the B. t. u. transferred to or from the air in contact with the surface per square foot per degree difference in temperature between the air and the surface.

The following coefficients are average values as determined by a formula attributed to Grashof, using the constants as recommended by Rietschel:

Table 2.

CONVECTION FACTOR "A."

B. t. u. per square foot per degree difference in temperature between the air and surface:

	Brick walls.	Glass.	Wood.
Air at rest as in air space construction.	.88	1.00	.83
Air with slow motion as in rooms.....	1.10	1.24	.83
Air outside of building..............	1.31	1.47	.84

COMBINED COEFFICIENT OF RADIATION AND CONVECTION.

It is convenient to combine the coefficients of radiation and convection as $K = R + A$. Then $M_R + M_A = K\ (t_2—t_o)$ or $K\ (t—t_1)$.

CONDUCTIVITY.

The amount of heat (M_c) that will be transmitted through a material having parallel surfaces due to a difference in temperature between these surfaces is termed the conductivity of the material. The amount of heat that a given material will transmit is directly proportional to the difference in temperature between the surfaces and inversely proportional to the thickness.

Let C = coefficient of conductivity. B. t. u. transmitted per square foot per hour per inch thickness per degree difference F. in temperature of the two surfaces

t_1 = temperature of inside surface.

t_2 = temperature of outside surface.

x = thickness of wall, inches.

Then $M_c = \frac{C}{X}(t_1—t_2)$.

It is obviously impossible to give a table of exact conductivities of the various materials of building construction, owing to the fact that two samples of the same kind of material will often be found to vary considerably both in density and conductivity.

The following table has been calculated by the author from various test data, and represents fair average results.

TABLE 3.

COEFFICIENT OF CONDUCTIVITY "C."

B. t. u. transmitted per square foot per hour per degree difference in temperature F. of the two surfaces.

Corkboard (all cork)	.32
Mineral wool, board waterproofed	.46
Indurated fiber board	—
Packed mineral wool, 16.3 lbs. per cu. ft	.35
Packed granulated cork, 6.25 lbs. per cu. ft	.35
Average wood	1.10
Average brick	6.00
Concrete (stone)	9.00
Mortar	10.00
*Glass	6.00
*Sand	2.20
*Fir at right angles to fibers	.75
*Walnut at right angles to fibers	.83
*Limestone, fine grained	14.80
*White marble, coarse grained	22.50

* Values given by Peclet.

The temperature of the wall surfaces t_1 and t_2 are unknown, the known temperatures being the temperature of the air (t) inside the building and the outside air (t_0). The elimination of the surface temperatures from the calculations is accomplished in the following manner:

The amount of heat received by the inside wall surface, amount conducted by the wall and the amount emitted by the outside surface must evidently be equal to one another.

Let u = the heat transmission of the wall per square foot per hour per degree difference in temperature of the air on the two sides.

$$u\,(t-t_0) = K_1\,(t-t_1) = \frac{C}{X}\,(t_1-t) = K_2\,(t_2-t_0) \quad (1)$$

$$u = \frac{1}{\frac{1}{K_1} + \frac{1}{K_2} + \frac{x}{c}} \quad (2)$$

If the combined radiation and convection coefficients are the same for both the inside and outside wall surfaces, then

$$K_1 = K_2 \text{ and } u = \frac{1}{\frac{2}{K} + \frac{x}{c}} \quad (3)$$

The factor $\frac{x}{c}$ for thin metal plates or glass is so small that it may safely be neglected in calculations. If the wall is composed of several layers of different materials in contact with one another (no air spaces), then,

$$u = \frac{1}{\frac{1}{K_1} + \frac{1}{K_2} + \left(\frac{x_1}{c_1} + \frac{x_2}{c_2} + \frac{x_3}{c_3} + \text{etc.}\right)} \quad (4)$$

in which x_1, x_2, x_3, etc., are the thicknesses of the various materials, c_1, c_2, c_3, etc., are the corresponding coefficients of conductivity, and K_1 and K_2 are the combined coefficients of radiation and convection for the outside and inside wall surfaces.

Example: Let it be required to determine the heat transmission (u) of a 13-inch brick wall per degree difference in temperature of the air on the two sides per square foot per hour. From Table 1 $R = .74$; from Table 2 $A = 1.10$; then $K = .74 + 1.10 = 1.84$; from Table 3 $C = 6$, $x = 13''$.

$$u = \frac{1}{\frac{2}{1.84} + \frac{13}{6}} = .31$$

Actual test gave .38 for the value of u (see Table 4). The calculated heat transmission of a 13-inch brick wall insulated with 4-inch corkboard is as follows:

$$u = \frac{1}{\frac{2}{1.84} + \frac{13}{6} + \frac{4}{.32}} = .063$$

Actual test gave .060 for the value of u.

HEAT TRANSMISSION OF AIR SPACE CONSTRUCTION.

Heat is transmitted through an air space from one surface to another by radiation and convection.

The calculation of the heat transmission in air space construction made up of 8⅞-inch spruce boards in four layers of two boards each and three air spaces follows. The value of K for each of the eight wood surfaces from Tables 1 and 2 is $K = .74 + .83 = 1.57$. C for wood $= 1.1$.

$$u = \frac{1}{\frac{8}{1.57} + \frac{8}{1.1}} = .082$$

The table of tests gives for this construction a value of $u = .112$.

The following calculation is for ordinary outside wood wall construction made up of clapboards, 1-inch sheathing, air space with ½-inch lath and plaster. $K = 1.57$; C for wood $= 1.1$; c for mortar $= 10$.

$$u = \frac{1}{\frac{4}{1.57} + \frac{1.7}{1.1} + \frac{.5}{10}} = .23$$

The following table gives the value of "u" from various tests and also the calculated value, using the data as given by Tables 1, 2 and 3:

TABLE 4.

TESTS OF VARIOUS CONSTRUCTIONS.

B. t. u. transmitted per degree difference in temperature of the air in contact with the surfaces per square foot per hour.

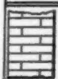
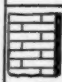
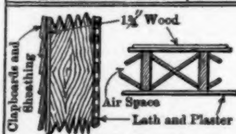
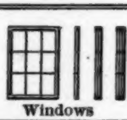
CONSTRUCTION	U BY TEST	U BY CALCULAT'N	TEST REPORTED BY
13" brick wall	.385	.31	Armstrong Cork Co.
1" corkboard (all cork)	.262	....	Armstrong Cork Co.
2" corkboard (all cork)	.135	....	W. Kennedy
3" corkboard (all cork)	.092	....	L. A. Harding
2" composition corkboard cork and asphalt	.185	....	Armstrong Cork Co.
4 layers ⅞" spruce boards	.198	....	Jno. E. Starr
⅛" steel plate	1.30	....	A. C. Willard
Corrugated sheet steel	1.50	....	Buffalo Forge Co.
2" mineral wool insulating board	.164	....	W. Kennedy
2" mineral wool insulating board, water-proofed	.185	....	C. L. Norton
2" indurated fiber insulating board	.208	....	W. Kennedy
4 ⅞" boards, 1 air space	.177	.162	Nonpareil Cork Co.
6 ⅞" boards, 2 air space	.144	.110	Nonpareil Cork Co.
8 ⅞" boards, 3 air space	.112	.082	Nonpareil Cork Co.
2 ⅞" boards and 1" corkboard	.135	.157	Nonpareil Cork Co.
3 ⅞" boards and 3" corkboard + 1" air space	.071	.067	Nonpareil Cork Co.
2 ⅞" boards and 2" corkboard	.108	.105	Nonpareil Cork Co.
2 ⅞" boards and 6" granulated cork	.048	.049	Armstrong Cork Co.
2 ⅞" boards and 6" mineral wool	.046	.049	Armstrong Cork Co.
13" brick wall + 2" corkboard	.114	.112	Armstrong Cork Co.
13" brick wall + 4" corkboard	.060	.063	Armstrong Cork Co.
5 ⅞" boards + 6" granulated cork + 1" air space	.060	.040	Nonpareil Cork Co.
5 ⅞" boards + 2" corkboard + 1" air space	.066	....	Nonpareil Cork Co.
2 ⅞" boards + 3" corkboard	.088	.087	Nonpareil Cork Co.
4 ⅞" boards + 1" corkboard	.160	.140	Nonpareil Cork Co.
3 ⅞" boards + 4" corkboard + 1" air space	.050	.056	Nonpareil Cork Co.

The following table has been calculated by means of the data given by Tables 1, 2, and 3. For glass the highest value for A in Table 3 was used.

TABLE 5.

HEAT TRANSMISSION OF BUILDING CONSTRUCTION

(CALCULATED BY MEANS OF TABLES 1, 2 AND 3)

Construction	Thickness Inches	B.t.u. Transmitted per Square Ft. per Hour — Air Temperature Difference 1°	20°	40°	60°	70°	80°
 K = 1.84, C = 6. Plain Brick Wall	9"	.390	7.8	15.6	23.4	27.3	31.2
	13"	.310	6.2	12.4	18.6	21.7	24.8
	18"	.344	4.9	9.8	14.7	17.1	19.6
	24"	.211	4.2	8.4	12.6	14.8	16.8
 K = 1.84, C = 6 for brick, C = 19 for mortar. Brick Wall Furred and Plastered	9"	.268	5.4	10.8	16.2	18.7	21.6
	13"	.219	4.4	8.8	13.2	15.3	17.6
	18"	.191	3.8	7.6	11.4	13.4	15.2
	24"	.160	3.2	6.4	9.6	11.2	12.8
 Wood Wall or Floor		.23	4.6	9.2	13.8	16.1	18.4
			K = .74 + .83 For all surfaces; C = 1.1 For wood; C = 10. For mortar				
 Hollow Tile	6"	.40	8.0	16.0	24.0	28.0	32.0
	12"	.35	7.0	14.0	21.0	24.5	28.0
 Concrete	2"	.76	15.2	30.4	45.6	53.2	60.8
	3"	.63	12.6	25.2	37.8	44.1	50.4
	4"	.58	11.6	23.2	34.8	40.6	46.4
	6"	.51	10.2	20.4	30.6	35.7	40.8
		K = 1.84	C = 9.				
 Windows	Single Sash	1.03	20.6	41.2	61.8	72.1	82.4
	Double Sash	.52	10.4	20.8	31.2	36.4	41.6
	Triple Sash	.35	7.0	14.0	21.0	24.5	28.0
		K = R + A = .595 + 1.47 = 2.065					

CCCXVIII.

THE FLOW OF AIR IN HEATING AND VENTILATING DUCTS, INCLUDING AN EXAMPLE IN DUCT DESIGN.

L. A. HARDING.

The present coefficient of friction as ordinarily used in general, the formula $h = .00022f\frac{V^2}{D}$ the value of f used is .0064. We find in the tests it varied from .0031 to .0042. These coefficients check up very well with some tests recently made by several German authorities and I believe they are fairly accurate. They were made in different parts of the country and made upon commercial installations. The tests to find the friction pressure loss by entry to branch ducts are rather important and they show that the friction loss by entry increases very materially as the angle increases between the branch and main. These experiments were conducted with air velocities of 1,500 to 2,500 feet a minute. The report also includes a chart for a design of both round and rectangular ducts, and also an example worked out showing the use of the chart.

The general form of the expression for the loss of head measured by the height of a column, in feet, of the medium flowing in a pipe is:

$$h_1 = f\frac{LR}{A}\frac{v^2}{2g} \quad (1)$$

in which

h_1 = the head lost in feet of air column
L = length of the pipe or duct in feet
R = perimeter of the pipe or duct in feet
A = area of the pipe or duct in square feet
LR = area of the rubbing surface in square feet
f = the coefficient of friction

v = velocity of flow (average over the cross-section) in feet per second

g = 32.16

$\frac{v^2}{2g}$ = the velocity head

Experiments on the flow of air in *smooth* sheet steel ducts varying in size from 12" to 48" diameter and with velocities ranging from 1,000 to 2,400 feet per minute show that the average value of f is .0037. The value of f that is used by various manufacturers in the calculation of published tables and diagrams is approximately .0062 and is undoubtedly too high.

If the measurements for head lost are made or stated in inches of water, formula (1) becomes

$$h_1 = \frac{h \times k}{12d} = f\,\frac{LR}{A} \times \frac{v^2}{2g}$$

or $$h = \frac{12d}{K} \times f \times \frac{LR}{A} \times \frac{v^2}{2g} \quad (2)$$

in which

h = head lost measured in inches of water

d = density of the air flowing (wt. per cu. ft.)
= .075 for 70° F.

K = density of the water in the manometer
= 62.4 for 70° F.

For a temperature of 70° F. (2) becomes

$$h = .00022\, f \frac{LR}{A} v^2 \quad (3)$$

and for round ducts 100 feet long,

$$h = .088\, f\, \frac{v^2}{D} \quad (4)$$ in which

D = diameter of the duct in feet.

If $f = .00372$ then $h = .000327\,\frac{v^2}{D}$ (5)

$f = .0062$ then $h = .000545\,\frac{v^2}{D}$ (6)

If Q = cu. ft. of air flowing per minute
= 60 Av or

$$v = \frac{Q}{60A}$$

Substituting the value of v in (3) we have

$$h = .00022\, f\, \frac{LRQ^2}{3600A^3}\ (7) \text{ or } Q = 4045\sqrt{\frac{h}{Lf}} \times \sqrt{\frac{A^3}{R}}\ (8)$$

From this equation it is evident that the head lost for a given value of Q will be the same for either round or rectangular ducts so long as the value of $\sqrt{\frac{A^3}{R}}$ remains the same in both cases.

For a value of $f = .0037$ and $L = 100$ feet.

$$Q = 6633\sqrt{h} \times \sqrt{\frac{A^3}{R}}\ (9) \quad \text{For round ducts} \sqrt{\frac{A^3}{R}} = .393\sqrt{D^5}$$

in which D = the diameter of the duct in feet.

$\therefore Q = 2607\sqrt{hD^5}$ (10) for smooth sheet steel ducts with no allowance for roughness of joints, etc.

For the value of $f = .0062$ as ordinarily used in the calculation of manufacturers' tables and charts.

$Q = 5140\sqrt{h} \times \sqrt{\frac{A^3}{R}}$ (11) which for round ducts reduces to

$$Q = 2020\sqrt{hD^5}\ (12)$$

The chart accompanying was calculated by means of equations (9) and (10). It was thought best to plat the chart for a value of $f = .0037$, corresponding to smooth ducts, and in using the chart to add a percentage which in the judgment of the designer would cover the increased friction due to rough joints, poor alignment, etc.

In this connection the writer would recommend the addition of at least 25 per cent. to the friction loss as read from the chart for the average well-constructed duct layout when proper allowance has been made for the ells or turns, loss through the register grills, etc.

It is convenient and simplifies the calculations to design a duct layout for equal friction pressure loss per foot of length. If we fix the maximum velocity in the last section farthest from fan, knowing the amount of air (Q) to be delivered through this

section, the head lost (h) per 100 feet is readily found from equations (9) or (10).

As the value of h is to remain constant, the value of the expression $\sqrt{\frac{A^3}{R}}$ for the various sections may be computed, from which the dimensions of the duct are obtained. For round ducts we have the relation

$$\frac{Q_1^2}{D_1^5} = \frac{Q_2^2}{D_2^5} = \frac{Q_3^2}{D_3^5} = \text{Etc. or } \frac{D_2}{D_1} = \left(\frac{Q_2}{Q_1}\right)^{\frac{2}{5}} \quad \frac{D_3}{D_1} = \left(\frac{Q_3}{Q_1}\right)^{\frac{2}{5}} \text{ Etc.}$$

When the various quantities of air flowing for the different sections are known and one diameter, the diameters of the remaining sections may be determined by the relation given above.

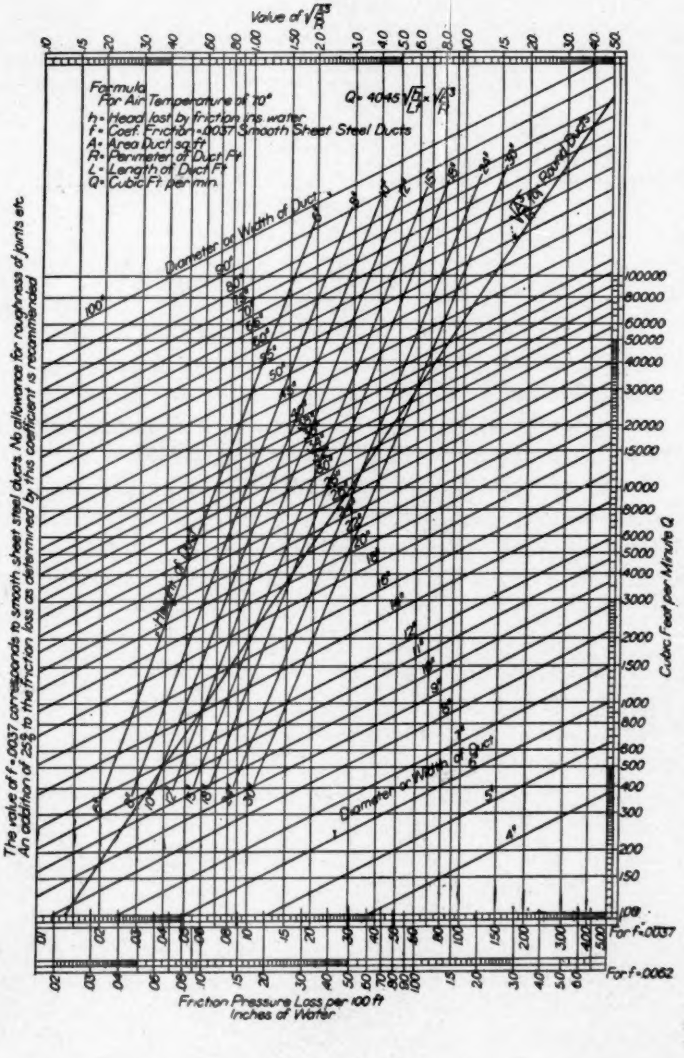
EXPLANATION OF CHART.

Locate the value of Q on the right hand side of chart; pass horizontally to the left to the intersection with the vertical pressure loss per 100 feet for which it is desired to design the duct. The diagonal diameter line passing through this intersection gives the diameter of the round duct required. The intersection of this diameter line with the line marked "$\sqrt{\frac{A^3}{R}}$ for round ducts" gives this value on the scale at the top of the chart. The equivalent dimensions of a rectangular duct for the same value of Q and h may be read from the intersection of the vertical with the diagonals marked "height of duct." The intersection of the diagonal line marked "diameter or width of duct" with this point gives the required width.

TABLE 2

ALLOWANCE FOR ELLS OR TURNS.

	RATIO OF THROAT RAD. TO DIAM. OR WDTH. R/W.	NO. DIAMS. OR WDTHS. TO ADD TO MEASURED LENGTH OF DUCT.	LOSS TABLE X VEL RR.
Sharp right angle turns....	round pipe	....	.90
Sharp right angle turns....	square pipe	....	1.30
Sharp angle 135°..........	....	....	.30
Right angle turns..........	$1\frac{5}{8}$ to 4	5	.15
Right angle turns..........	1.5	6	....
Right angle turns..........	1.2	9	....
Right angle turns..........	1.0	10	.25
Right angle turns..........	.75	16	....
Right angle turns..........	.5	30	....
Right angle turns..........	.30	58	....
Right angle turns..........	.25	68	....
Enlargement of round pipe slope 10%..........			23
Entrance to pipe..........			48


Value of $\sqrt{\frac{R}{A^3}}$
Formula
For Air Temperature of 70°
h = Head lost by friction ins water
f = Coef. Friction = .0037 Smooth Sheet Steel Ducts
A = Area Duct sq. ft
R = Perimeter of Duct Ft
L = Length of Duct Ft
Q = Cubic Ft per min
Diameter or Width of Duct
Height of Duct
Cubic Feet per Minute Q
For f = .0037
For f = .0062
Friction Pressure Loss per 100 ft
Inches of Water
The value of f = .0037 corresponds to smooth sheet steel ducts. No allowance for roughness of joints etc.
An addition of 25% to the friction loss as determined by this coefficient is recommended

The following data on friction pressure loss by entry to branch ducts was determined by the writer from experiments conducted in 1911, the size of the main being 24" and the branches 9½" in diameter respectively for velocities ranging from 1,000 to 2,000 feet per minute.

TABLE 3

ANGLE OF THE BRANCH DEGREES	FRICTION PRESSURE LOSS = TABLE X VELOCITY PRESSURE IN BRANCH.
15°	.09
30°	.17
45°	.22
60°	.44

EXAMPLE IN THE USE OF CHART.

Let it be required to proportion the "trunk line" air duct layout as shown by the accompanying figure.

Allowance for ell section "B": R = 1.2W. Width of duct, 3.5 feet. Add 3.5 x 9 = 31.5.

For ell section "F": R = 1.2W. Width of duct, 3 feet. Add 3 x 9 = 27 feet.

For ell section "F" at base of riser: R = W. Height of duct, 1.5 feet. Add 1.5 x 10 = 15 feet.

For ell section "G": R = W. Height of duct, 1.5 feet. Add 1.5 x 10 = 15.

For ell section "H": R = W. Width of duct, 1.6 feet. Add 1.6 x 10 = 16 feet.

For ell section "L": R = W. Width of duct, .67 feet. Add .67 x 10, say 7 feet.

Total equivalent length of duct for figuring the friction is 32 + 27 + 15 + 15 + 16 + 7 + 155 = 267 feet.

Total friction pressure loss for the main, including allowance for the ells, is therefore 267/100 × .05 = .134" water.

The final velocity pressure through the free area of the register grill at 400 feet per minute is .0105 inch. The loss through the register grill where the free area is equal to one-half the total area is approximately equal to 1½ times the velocity pressure, or 1½ × .0105 = .016 inch.

The total pressure required at the beginning of the main duct will be the sum of the lost heads or pressures plus the final velocity pressure, or .134 + .016 + .0.11 = .16 inch.

The total pressure at the last register, section "L," will be: .016 + .011 = .027 inch.

Draw a horizontal line to any convenient scale representing a length equal to 267 feet, as shown by the accompanying figure. At the left hand end on the vertical lay off .027 inch to scale; at the right hand end on the vertical lay off .16 inch to the same scale. A line connecting these two points will give the total pressure, to scale, at any point in the main and is convenient to use in ascertaining the total pressure available at any point where a branch main or branch is taken off.

For example: The branch main in the basement, M to R. The total pressure available in the main duct where this branch is taken off is .106 inch. The total pressure at the last register, section R, is .0105 + 1½ × .0105 = .026 inch.

The allowable pressure loss in this branch is therefore .106 — .026 = .08 inch. The total equivalent length of the branch, including two ells, is 72 feet, which gives .08 × 100/72 = .11 inch per 100 feet as the allowable loss. As this includes the 25 per cent. allowance for rough joints, etc., the corresponding pressure loss line on the chart to use will be $\frac{.11}{1.25}$ or .09 inch.

Referring to chart and reading on the .09 inch line in each case, we have the following sizes for this branch:

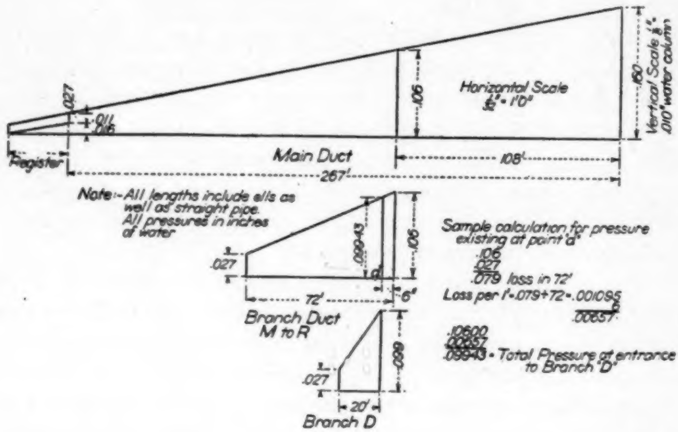
TABLE 4

SIZE OF SECTIONS FOR BRANCH DUCT M to R FRICTION LOSS = .09" PER 100 FEET

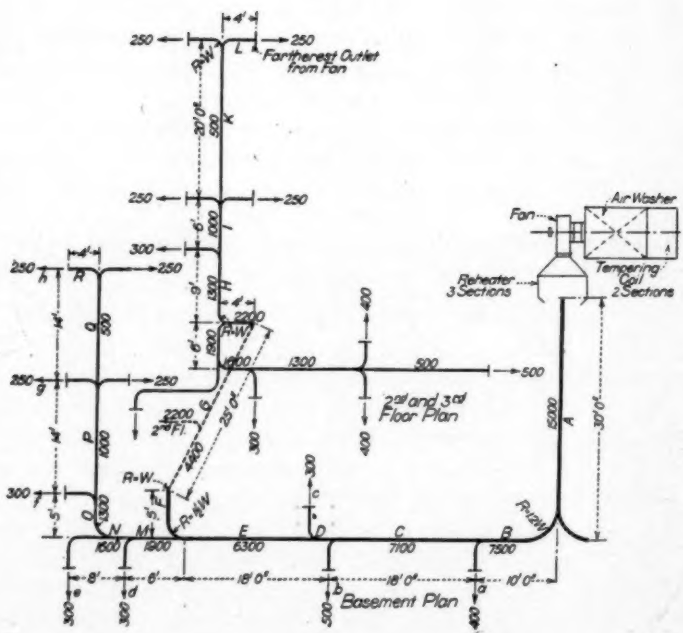
SEC.	CU. FT. PER MIN. Q.	SIZE OF DUCT.		LENGTH + ALLOWANCE FOR ELLS.
		DIAMETER.	EQUIV. RECTANGLE.	
M..........	1900	17.5	12 × 21.5	6
N..........	1600	16.5	12 × 18.5	6
O..........	1300	15	10 × 19	5 + 16
P..........	1000	13.5	10 × 15	14
Q..........	500	10.75	8 × 11	14
R..........	250	7.75	6 × 9	4 + 7

Total length including allowance for ells = 72 feet.

Branch "D."—The length of this branch, including allowance for one ell, is 20 feet. The total pressure in the branch main at the point where "D" is taken off is .09 inch. The total pressure at the end of the branch at the register is .026 inch. We may therefore lose .09 — .026, or .064 inch in 20 feet, or .064 × $\frac{100}{20}$ = .32 inch per 100 feet. The corresponding diagonal



Horizontal Scale
Vertical Scale
.010" water column
.160
.106
.027
.011
.016
Register
Main Duct
108'
267'
Note:- All lengths include ells as well as straight pipe. All pressures in inches of water
.027
.09943
.106
72'
6'
Branch Duct M to R
Sample calculation for pressure existing at point 'a'
.106
.027
.079 loss in 72'
Loss per 1' = .079 ÷ 72 = .001095
.00657
.10600
.00657
.09943 = Total Pressure at entrance to Branch "D"
.027
.039
20'
Branch D



Farthest Outlet from Fan
Fan
Air Washer
Reheater 3 Sections
Tempering Coil 2 Sections
2nd and 3rd Floor Plan
Basement Plan

pressure line on the chart to use will be $\frac{.32}{1.25}$, or .26 inch per 100 feet.

As this branch is to carry 300 cubic feet per minute, it would require a 6⅝-inch diameter or a 6-inch by 6½-inch rectangular duct to consume .064 inch in a 20-foot length. The area of this branch would be 39 square inches, or .27 square foot, and the velocity 300/.278 = 1,111 feet per minute. As this velocity is entirely too high to lead direct into the register box, the branch should be enlarged to an area corresponding to a velocity of 600 feet per minute, or 300/600 = .50 square foot, or 6-inch by 12-inch section, and a damper provided to give the extra frictional resistance to bring the loss up to .064 inch. This condition will, of course, be found to exist for all of the branches leading to the registers with the exception of the last one "L" at the end of the main duct. The pressure loss by entry from the plenum chamber to a duct in the single duct system of distribution is assumed to be .48 of the velocity pressure in the duct. The pressure loss in the gradually tapered section connecting the heater and main duct in the layout shown will probably not run higher than one-third the velocity pressure corresponding to 1,309 feet per minute velocity, or 1/3 × .01 = .0033.

REQUIRED PRESSURE RATING OF FAN.

Assuming that the heater sections have been figured for a velocity of 1,200 feet per minute through the clear area and the washer for 400 to 500 feet per minute, the total losses will then be:

Main duct	.134″
Entrance to main duct	.003″
Tempering coils (8 rows pipe)	.210″
Air washer	.260″
Reheater (12 rows pipe)	.300″
Register grill (1.5 × V. P.)	.016″
Total loss by friction	.923″
Final velocity pressure at 400 ft. per min.	.011″
Total	.934″

Say 1″ water.

CCCXIX.

THE USE OF STEAM FROM THE RECEIVER OF A COMPOUND ENGINE.

AUGUST BEAURRIENNE.

The use of steam from the receiver of a compound engine has been for the last few years the object of many studies and applications in Germany, Belgium and France. I thought that an account of these theoretical and experimental researches would be of interest. From the results of the researches of which the principal authors are Messrs. Eberlé and Ludwig Schneider, I shall endeavor to draw an approximate method of determining the conditions of compound engine operation corresponding to the most economic production of required quantities of power and of steam for heating.

In a combined plant, when the quantity of steam necessary for heating exceeds that spent by a steam engine in giving the power required (the exhaust steam keeping a sufficient temperature for heating), it is natural to make use of a single-cylinder engine, or of a compound engine, the exhaust of which passes through the heating system. But it often occurs that the quantity of steam sufficing for heating purposes is lower than the steam consumption of the engine, or that the steam for some heating operations must have a temperature relatively high and consequently it must be at a pressure incompatible with such utilization of the exhaust.

Then we are naturally induced first to expand the steam in a cylinder from the boiler pressure to the heating pressure. When it leaves this cylinder, the steam is divided into two parts; the first feeds the heating system, the other is expanded in a second cylinder from the receiver pressure to a pressure varying, according to conditions, between atmospheric pressure and a high vacuum. Sometimes steam from the receiver will feed a special heating system, designed for a high temperature, and

exhaust steam from the low-pressure cylinder will be used for another heating plant.

In an ordinary compound engine the admission in the low-pressure cylinder is regulated in such a way that the admission volume is equal to the volume of the high-pressure cylinder. If we send a part of the steam to the heating system, and if we were to keep the same admission, the pressure in the receiver would fall. To keep the same pressure it is necessary to diminish the steam admission in the low-pressure cylinder. This decreased admission will be obtained by means of a regulator, which is governed by the receiver pressure and works to keep it constant.

Let us consider a compound engine indicating 400 hp. when working without diverting steam from the receiver, and suppose that the quantity of steam admitted in the high-pressure cylinder is 5,000 lbs. If we take 1,000 lbs. from the receiver for heating, the pressure falls, but the admission regulator of the low-pressure cylinder works to diminish the admission and the receiver pressure is restored. But the low-pressure cylinder receiving a smaller quantity of steam gives less power. The engine speed slackens, then the speed regulator works to increase the admission in the high-pressure cylinder, which supplies a greater power and a greater quantity of steam to the receiver. The quantity used for heating purposes being the same, the low-pressure cylinder receives also more steam. But the low-pressure cylinder does not receive so much steam as the high-pressure, and, if the power were equal on the two cylinders for the ordinary working, it is not so now. In a tandem engine this difference will bring no trouble; but in a compound engine, with two parallel cylinders, of which the pistons are connected by two cranks, the difference in the power given out by the two cylinders will necessitate the increase of the fly-wheel weight.

To search into and understand the effect of taking steam from the receiver, we should naturally be tempted to look upon every cylinder as a single engine, and to admit that a given quantity of steam under a given pressure admitted in the cylinder will supply a definite amount of power. Really this is not so, because for a given admission in the low-pressure cylinder, and a given pressure in the receiver, the state of steam, its

degree of superheat, or its moisture, depend on the power supplied in the high-pressure cylinder. The same weight of steam entering the low-pressure cylinder has not given the same power and has not been submitted to the same heat exchanges in the high-pressure cylinder when it has been expanded alone, as when it has been expanded with another quantity of steam taken afterward from the receiver.

On the other hand, in the low-pressure cylinder, when the quantity of steam taken from the receiver for heating purposes is very large, the expansion becomes exaggerated; a small weight of steam at a rather low temperature is submitted to the reheating action of a large heating surface where there is a steam jacket. The quantity of heat so acquired is often greater than the quantity converted into power. So Mr. Eberlé has met an example in which steam entering the low-pressure cylinder with 20 per cent. water was slightly superheated at the exhaust.

According as the cylinders have or have not steam jackets and according as the total load is on the two cylinders, the conditions of expansion are not the same for the same admission and equal initial and final pressures. Professor Ludwig Schneider has studied a great many indicator diagrams of an engine, of which the elements are:

Diameter of the high-pressure cylinder	1 ft. 7 11/16 in.
Diameter of the low-pressure cylinder	2 ft. 5 17/32 in.
Stroke	3 ft. 7 9/32 in.
Number of revolutions per minute	107
Steam, absolute pressure	213.5
Temperature of steam, degrees	572
Absolute pressure in the receiver, lbs	73.5
Absolute pressure in the condenser, lbs	8

Professor Schneider has studied the variation of the indicated horsepower supplied by the high-pressure cylinder for full, three-fourths, one-half and one-fourth load, and for quantities of steam taken from the receiver varying between zero and 46 per cent. of the total consumption of the engine. The results show that the percentage of steam taken from the receiver has no influence on the efficiency of a given weight of steam in the high-pressure cylinder.

For different pressures in the receiver, that is to say, for other back pressures on the high-pressure piston, the corresponding quantity of steam and power is given. (Fig. 1.)

They are determinated as follows: The power may be theoretically increased or diminished by the quantity

$$D \times \frac{\pi d^2}{4} \times \frac{2n}{60} \times L$$

in which D is the difference of back pressure; d, diameter of the piston; L, the length of stroke; n, number of revolutions per minute.

This quantity would be 102 hp. for every variation of back pressure equal to the atmospheric pressure (14.7 lbs.), but, on

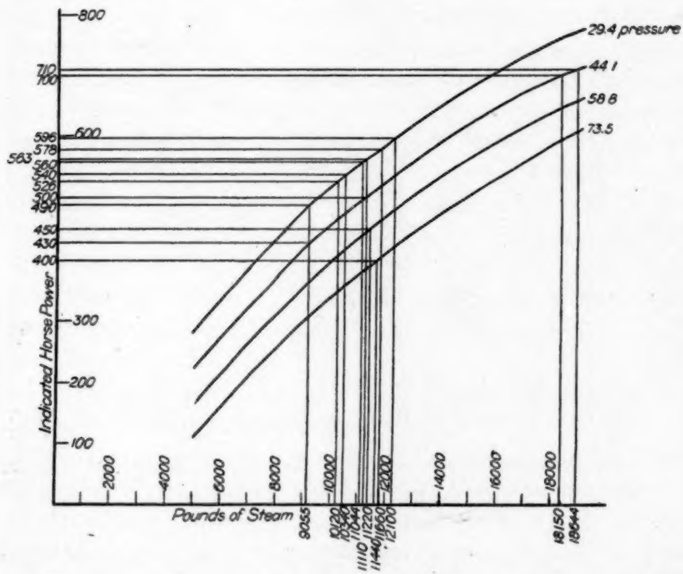


FIG. 1.—STEAM CONSUMPTION IN HIGH-PRESSURE CYLINDER FOR DIFFERENT RECEIVER PRESSURES, THE PRESSURES TAKEN BEING 2, 3, 4 AND 5 ATMOSPHERES.

account of the long compression following the exhaust in the high-pressure cylinder of a compound engine, the main difference of pressure during the stroke is much smaller than the difference of pressure in the receiver. Professor Schneider's tables show that the main difference of power is 58 hp. for every difference of receiver pressure equal to the atmospheric pres-

sure. The curves are established for the receiver pressures of 73.5, 58.8, 44.1 and 29.4 lbs. absolute.

Professor Schneider has also determined the variations in power in the low-pressure cylinder for several admission pressures (receiver pressures) and for different loads. The results are indicated by the curves. (Fig. 2.) These curves show for each admission pressure how the indicated power supplied varies with the quantity of the steam. However, if we substitute for the four curves corresponding to the same admission

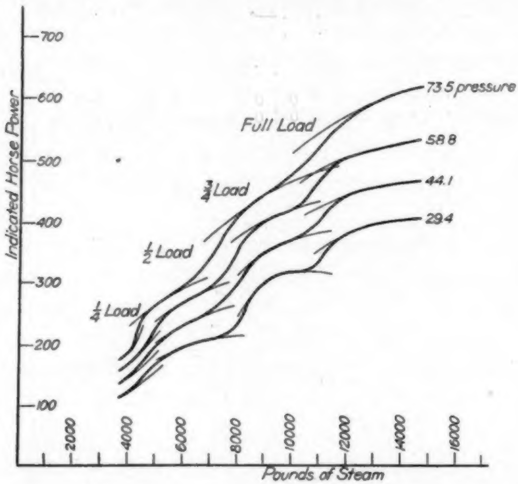


FIG. 2.—HORSE-POWER DEVELOPED IN LOW-PRESSURE CYLINDER FOR DIFFERENT RECEIVER PRESSURES AND THE TOTAL STEAM CONSUMPTION CORRESPONDING.

pressure the one curve drawn thicker (Fig. 2), we shall introduce in the measure of the power a mistake not greater than 10 per cent. For the absolute pressures of 58.8, 44.1 and 29.4 lbs., the error is somewhat larger, but remains within such limits that it may be neglected, at least in a preliminary consideration.

In the low-pressure cylinder the compression period is very short, and the difference of indicated hp. corresponding to a pressure difference in condenser is given by

$$0.95 \times D \times \frac{\pi d^2}{4} \times \frac{2n}{60} \times L.$$

From this formula I have drawn the curves. (Figs. 3, 4, 5 and 6.)

We have now all the necessary elements to find the working condition of the engine for the fixed conditions of receiver pressure, exhaust pressure, quantity of steam entering the high-pressure cylinder and quantity taken from the receiver.

First: Let us consider a constant power and a constant quantity of steam to be taken from the receiver—for instance, of 800 hp. and a quantity of steam of 5,500 lbs. We shall study the working conditions of the engine for several receiver absolute pressures.

1. Receiver pressure, 73.5 lbs. Supposing that the high-pressure cylinder supplied 400 hp. from the curve. (Fig. 1.) We see that the corresponding steam consumption is 11,440 lbs. For the admission in the low-pressure cylinder there remains 11,440 — 5,500 = 5,940 lbs. The low-pressure cylinder, working with the high vacuum (Fig. 3), shows the corresponding indicated output as 410 hp. The total output is 810, or practically what was wanted. The consumption per indicated horsepower is 14.1 lb.

2. Receiver pressure, 58.8 lbs. Calculating in the same way, we find that the steam consumption per indicated horsepower is 13.85 lbs.

3. Received pressure, 44.1 lbs. Steam consumption per horsepower figures out 13.71 lbs.

4. Receiver pressure, 29.4 lbs. Steam consumption, 12.76 lbs.

For the same power the steam consumption is less the smaller the receiver pressure. This is natural since the total quantity of steam is submitted to a bigger expansion in the high pressure cylinder, while a part of this steam only is submitted to a smaller expansion in the low-pressure cylinder. The receiver pressure will be chosen according to the needs of the heating system and will be as low as possible.

However, the preceding study has shown that the total steam consumption is increased only by 800 (13.85 — 12.70 = 920 lbs.) when the receiver pressure changes from 73.5 to 29.4 lbs. We shall have to consider if the increase of surface of the heating system or of mains will not bring an increase of money invest-

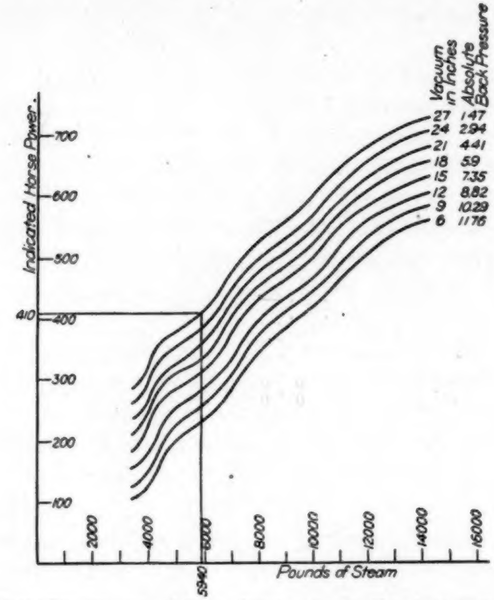


FIG. 3.—HORSE-POWER AND TOTAL STEAM WITH RECEIVER PRESSURE OF 5 ATMOSPHERES.

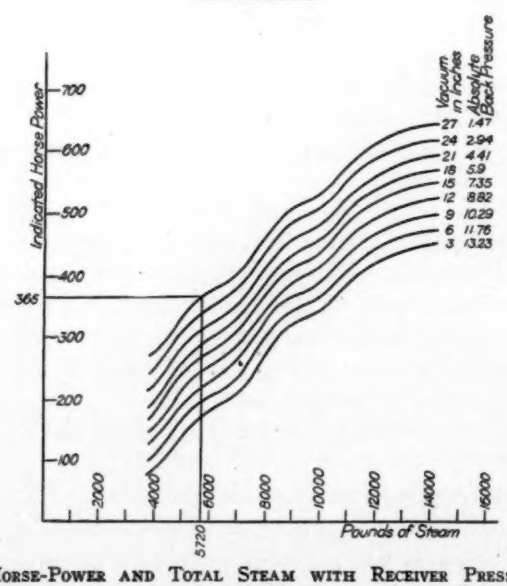


FIG. 4.—HORSE-POWER AND TOTAL STEAM WITH RECEIVER PRESSURE OF 4 ATMOSPHERES.

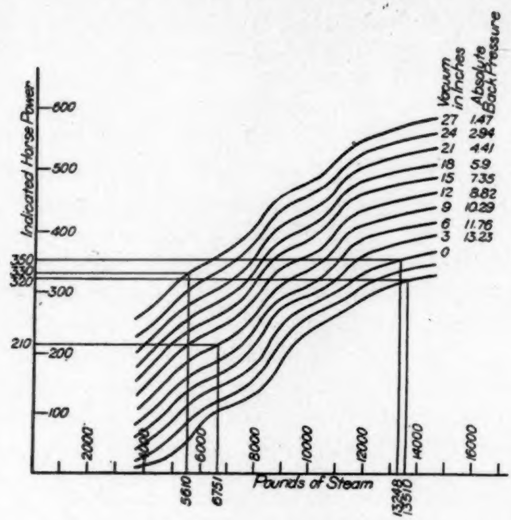


FIG. 5.—HORSE-POWER AND TOTAL STEAM WITH RECEIVER PRESSURE OF 3 ATMOSPHERES.

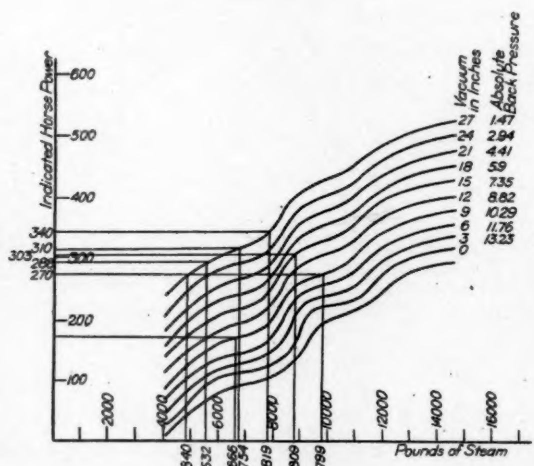


FIG. 6.—HORSE-POWER AND TOTAL STEAM WITH RECEIVER PRESSURE OF 2 ATMOSPHERES.

ment on which the interest and retiring fund will be higher than the price of the extra steam consumption.

SIZE OF THE LOW-PRESSURE CYLINDER.

When the quantity of steam taken from the receiver is a large part of the total consumption, the low-pressure cylinder must be evidently smaller than if the whole steam passed through. The general problem consists in calculating the best proportions of a compound engine to realize given quantities of power and steam for heating.

First, it is necessary to calculate the indicated horsepower corresponding to the given output in kilowatts. This is to be obtained from the mechanical efficiency of the engine and the efficiency of the dynamo.

Mr. Delafond has found from a great number of experiments that

$$P_e = 0.9\,P_i - 16 \text{ for a non-condensing engine}$$
$$P_e = 0.95\,P_i - 12 \text{ for a condensing engine}$$

Where P_i is the indicated horsepower and P_e is the horsepower of output.

We shall take the mean value

$$P_e = 0.925\,P_i - 14$$

$$P_i = \frac{P_e + 14}{0.925}$$

$$W = 0.746\,kP_e$$

$$P_e = \frac{W}{0.746\,k}$$

k being the efficiency of the dynamo and transmission, and W being the output in kilowatts. This coefficient increases with the load.

One can write

$$P_i = \frac{\dfrac{W}{0.746\,k} + 14}{0.925}$$

In giving to k its different values for different loads in a dynamo of a given maximum output, we shall have a curve, and, making the same calculations for different dynamos, we shall

have series of curves from which may be ascertained the indicated horsepower corresponding to any output of any dynamo.

All the curves shown have been drawn for a particular engine of which the high-pressure cylinder volume is V. For another engine having proportional dimensions, but of which the high-pressure cylinder is V_1, the power supplied will be $P_1 = \frac{V_1}{V} P$ for the same condition of pressure admission and for the same percentage of steam taken from the receiver.

We shall assume that the steam consumption per indicated horsepower in this same condition is

$$\frac{C_1}{P_1} = M \frac{C}{P}$$

M being a function of $\frac{V_1}{V}$, decreasing when $\frac{V_1}{V}$ is increasing.

These variations are determined by experiments on similar single-cylinder engines, and are expressed by

$$M = 1.222 - 0.222 \frac{V_1}{V}$$

We find finally

$$C = \frac{V}{V_1} \times \frac{1}{1.222 - 0.222 \frac{V_1}{V}} \times C_1$$

The curve (Fig. 7) shows the value of the ratio $\frac{C}{C_1}$ for different values of $\frac{V_1}{V}$

When we have chosen intuitively the dimensions of an engine, to search into and understand its working as a power and heating producer we proceed as follows:

EXAMPLE.

The given conditions are those which were to be realized a few years ago in one of the film factories of the Pathé Cinematograph Company. The quantities of power and steam for heating were:

1. Electric output 150 kw. during the day and 180 kw. in the evening and winter mornings.

2. There are different heating systems which are to be divided into four kinds.

A—B. t. u. necessary for the ordinary heating of the buildings. The maximum output per hour is 2,120,000 B. t. u. The variations of their number for every mean day of every month of the year may be shown by the curve.

B—B. t. u. necessary for the drying rooms. The maximum output per hour is 2,120,000 B. t. u. The variations are not so

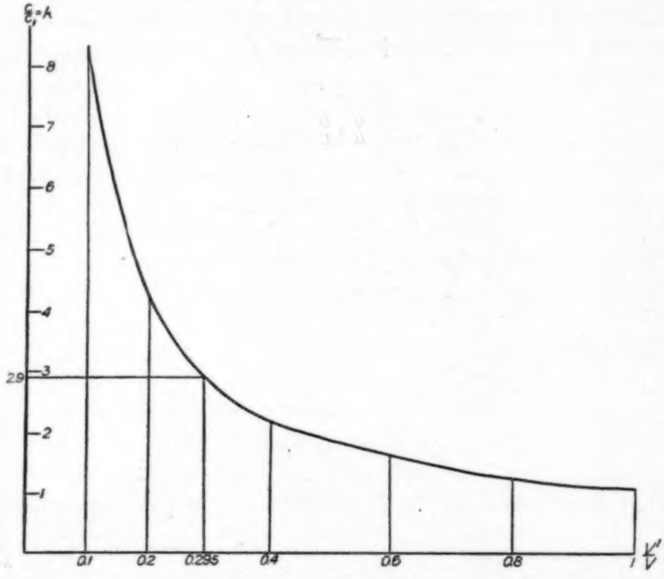


Fig. 7.—Curve of Relation between Cylinder Volume Ratios and Steam Consumption Ratios.

large as those of the heating, for the heat corresponding to water evaporation has to be supplied continuously.

For the heating systems *A* and *B*, steam at temperatures ranging from 158 to 210 deg. F. may be used. The exhaust steam of the engine, or a water circulation heated by such steam, may be used. The vacuum on the low-pressure cylinder varies with the heating load.

C—B. t. u. necessary to heat photographic baths by steam directly mixed with them; maximum quantity, 1,200,000 B. t. u.

This consumption lasts for one hour only in the morning, falling to 200,000 B. t. u., rising to 600,000 after luncheon for another hour, and falling back to 200,000 B. t. u.

D—B. t. u. necessary for heating hot water for various purposes and for dry kilns requiring an inside temperature over 175 deg.; maximum quantity 608,000 B. t. u.

The heat for *C* and *D* has to be supplied by steam under a minimum effective pressure of 7 lbs. per square inch. If the distributing mains have a total loss of pressure of 7 lbs. on full load we must consider a back pressure of 14 lbs. The steam will have to be taken from a special engine or from the receiver of a compound engine.

Let us consider the first period of the working on a winter morning. The electric load being 180 kw. and the heating loads *A* and *B*, 4,240,000 B. t. u., corresponding to 4,342 lbs. at the exhaust of the low-pressure cylinder, and to 4,825 lbs. at the admission (10 per cent. loss for condensation in the engine). The requirements for *C* and *D* total 1,808,000 B. t. u., corresponding to 1,854 lbs. of steam at the admission pressure (steam being superheated, there is no condensation in the high-pressure cylinder).

The indicated horsepower corresponding to 180 kw. is 310 hp. The engine of which the small cylinder volume is V, receiving steam at 212 lbs. absolute pressure and 572 deg. temperature, working with 44.1 lbs. absolute receiver pressure, no back pressure and 27 per cent. [1,854÷(4,825+1,854)] steam taken from the receiver supplies (Figs. 1 and 5).

In high-pressure cylinder 700 hp. with 18,150 lbs.
In low-pressure cylinder 350 hp. with 13,248 lbs.
Total output 1,050 hp.

The similar engine capable of supplying 310 hp. will have a small cylinder

$$V_1 = \tfrac{310}{1050} V = 0.295 V.$$

The steam consumption of this engine may then be calculated by means of the curve of Fig. 7.

For the high-pressure cylinder	6,256
For the low-pressure cylinder	4,565
Receiver steam	1,691

This engine does not give enough steam for the heating system, being 1,691 lbs. instead of 1,830 from the receiver, and 4,565 instead of 4,825 for the low-pressure cylinder.

At full load it will be possible to increase the steam consumption per horsepower by increasing the exhaust pressure. This will allow for use in the heating system of smaller heating surface or smaller mains. But we shall have to take an engine somewhat larger; for instance, $V_1=0.3V$, that is $P_1=0.3P$.

From Fig. 7 we see that $\frac{C}{C_1} = 2.8$. Instead of studying the engine V, giving 310 hp. and the steam consumption of 1,830 and 4,825, we shall consider the engine supplying $310 \times \frac{V}{V_1}$ $=1,030$ hp. and a steam consumption $1,830 \times 2.8 = 5,134$ lbs. of steam taken from the receiver, and $4,285 \times 2.8 = 13,510$ lbs. entering the low-pressure cylinder. This means $13,510 + 5,134$ $= 18,644$ lbs. entering the high-pressure cylinder.

The curves of Figs. 1 and 5 show that for 44.1 lbs. receiver pressure the indicated horsepower is

For 18,644 lb. in the high-pressure cylinder	710
For 13,510 lb. in the low-pressure cylinder	320
Total indicated output	1,030

In these conditions the requirements of steam for power and heating are exactly balanced.

Consider the load W equals 150 kw. The heating loads *a* and *b* equal 4,240,000 B. t. u., corresponding to 4,285 lbs. (including condensation in the engine). The loads *c* and *d* equal 1,800,000 B. t. u., corresponding to 18,030 lbs. We have the same quantity of steam and a smaller power load. We shall send through the engine the quantity of steam able to supply 150 kw. and the difference will pass through the heating system through an automatic reducing valve.

Working of the Engine During a January Afternoon.

Load=150 kw.

A+B=1,620,000 B. t. u., corresponding to 2,411 lbs.

C+D=813,600 B. t. u., corresponding to 823 lbs.

For the engine V, the corresponding quantities are: $P_1=866$ hp.; A+B=6,751 lbs.; C+D, 2,305 lbs.

That is to say, 9,056 lbs., giving in the high-pressure cylinder, 430 hp. and 6,751 lbs., giving in the low-pressure cylinder, 210 hp., a total output of 640 hp., instead of 866 hp. These quantities are for an absolute back pressure of 10.3 lbs., which gives a steam temperature high enough for this load of the heating system.

If the system taking steam from the receiver has pipes sufficiently large to deliver 810,600 B. t. u. with 29 lbs. total pressure, the utilization of steam in the high-pressure cylinder will be better and the same quantity of steam will give 660 hp.

To get 866 hp. it will be necessary to use in the high-pressure cylinder 12,100 lbs., supplying 596 hp. In the low-pressure cylinder, 9,795 lbs., supplying 270 hp., makes a total output of 866 hp. The excess of steam at the exhaust of the low-pressure cylinder will have to be condensed by water to keep the vacuum.

Let us calculate how large will be the total steam consumption for power and heating, the engine being run condensing under a high vacuum, live steam being used in the heating system A+B, and receiver steam in the heating system C+D. The curves show that it will be necessary to supply 10,120 lbs. to the engine. To the heating system must be supplied 6,075 lbs. (6,751 x 0.9). The total consumption is 16,195 lbs., which is larger than 12,100 lbs., to be supplied when the engine is running under a reduced vacuum.

Working of the Engine in Summer.

The steam consumption C+D is the same as in the winter; the quantity A is naught; B becomes as low as 1,200,000 B. t. u. during the afternoon. The vacuum in the low pressure cylinder may be 18 in., corresponding to the steam temperature, 170 deg. F. We have A+B=1,200,000 B. t. u., 1,366 lbs. C+D= 812,600 B. t. u., 823 lbs.

For the engine the corresponding quantities are: A+B= 1,366 x 2.8=3,824. C+D=823 x 2.8=2,304.

Let us consider three kinds of working the installation:

1. Exhaust steam in B receiver steam for C+D. From the curves we deduce

11,110 lb. in high-pressure supply	563 hp.
8,806 lb. in low-pressure supply	303 hp.
Total power	866 hp

2. Live steam in system B; receiver steam for system C+D; engine running with high vacuum

We must supply to the engine	10,120 lb.
To the heating	3,824 lb.
Total consumption	13,944 lb.

3. Receiver in system B and expanded receiver steam for system C+D; the engine running condensing with high vacuum.

The quantity of receiver steam is 3,824 lbs., plus 2,304 lbs., that is, 6,128 lbs. In the engine

11,660 in the high-pressure cylinder supplying	578 hp.
11,660 in the low-pressure cylinder supplying	288 hp.
Total output	866 hp.

The steam consumptions are 11,110 lbs., 13,944 lbs., and 11,660 lbs. The smallest is the first corresponding to the reduced vacuum and use of exhaust steam.

But when the steam consumption for *B* becomes smaller and decreases to B=600,000 B. t. u., for instance, it is better to work the low-pressure cylinder under a high vacuum and to take receiver steam for the system B. The same calculation shows that the corresponding consumptions are 10,890 lbs. and 11,190 lbs.

If we consider the main heating load, we see that generally the corresponding steam consumption is smaller than that necessary for power. In these conditions the low-pressure cylinder is working under a reduced vacuum for a great part of the year. The best condition will be obtained by the use of two compound engines with two dynamos, each having a 90-kw. output.

When the heating system is working on a full load, the two engines will be run under a back pressure; when the load is smaller they will be run under a reduced vacuum. When the steam consumption of heating system A+B becomes near the consumption of an engine supplying 75 kw. (half of the ordinary load) one of the engines will supply the exhaust steam for system A+B, and the other will be run condensing under a high vacuum. The steam for C+D will be taken from the two receivers, so we shall not have the admission to the low-pressure cylinders too greatly reduced.

When the heat consumption B becomes smaller than 450,000 B. t. u., it becomes better to run the two engines condensing, taking the whole steam for heating from the receivers.

[With this paper the author supplied tables showing the results obtained with some engines in France and Germany; a drawing of a regulator of the steam admission to the low-pressure cylinder of a compound engine—this regulator governed by the receiver pressure, and a drawing of a special reducing valve to lower the receiver pressure to that of low-pressure heating system. These were, however, lost in transmission, but any one interested can get the information about them from the author.]

TRANSACTIONS

OF THE

SEMI-ANNUAL MEETING

Buffalo, N. Y., July 17, 18 and 19, 1913.

CCCXX.

PROCEEDINGS

OF THE

SEMI-ANNUAL MEETING

AT

THE HOTEL STATLER, BUFFALO, NEW YORK,

FIRST DAY—MORNING SESSION.

Thursday, July 17, 1913.

The meeting was called to order at 10:40 A. M. by President Hale.

President Hale read his address.

Mr. Frank L. Busey then outlined the entertainment scheme for ladies, guests and members during the convention period.

President Hale: As we will be the guests of the American Radiator Company to-morrow at their Thermal Research Building, we will be very glad to hear from Mr. Soule, if he has any remarks to make in reference to his plans or the plans for getting members to the test building and what the plans are for the day.

Mr. Soule: Why, the principal thing is for us all to be ready to start from here on the car at 8:45 in the morning, so that we can get to the Research Building promptly, and have plenty of time to see those three tests going on. We are only to be there until 12:30, and if there is very much delay it will not leave very much time to spend on the test. We have everything ready, everything that I can think of.

President Hale: Then we will take the car at 8:45 in front of the hotel.

Mr. Busey: On the Friday afternoon trip, about 2 o'clock we should be ready to go out to the Buffalo Forge Company's

building. Cars leave the hotel. I have not arranged for a special car, because I did not know just when we would be through with our lunch. I have arranged when we get there to divide into groups to go through the plant.

President Hale: The Secretary has some reports to make before we go ahead with the regular business.

Secretary Scott: The first thing I have to say is a pleasant word or message from two of our good members who are abroad at the present time, Mr. Frank T. Chapman and the former Secretary, Mr. W. W. Macon. We received a cablegram from some place in Germany, which says: "Best wishes for a successful meeting." Signed, "Chapman and Macon."

Perhaps I might say just one word about the visit to the Bureau of Thermal Research to-morrow. In correspondence with those who have that visit in charge they have impressed upon the secretary the importance of getting members ready to start promptly at 8:45 o'clock to-morrow morning. There is no siding available for the street railway company to hold its cars here, and it will hold up traffic if we are not ready to start promptly at 8:45. As to the number who will go out there, I had a letter from the manager of the plant and he asked me to let him know how many cars we would want. I told him that we would probably want two cars—there would be enough people to fill two cars. I imagine from the registration that we will probably require that many. If there are those present who do not intend to go, I wish they would so advise the Registration Desk, so if it is not necessary to take the two cars we can advise the officials.

It is going to take a certain time, as I understand it, to run off those tests. By leaving here at 8:45 we can spend the necessary time to witness the tests and get back here at 12:45 for lunch. Then, as Mr. Busey explained, we will have lunch here or wherever the members and guests choose, and visit the Buffalo Forge Co. plant.

There is another invitation which came to the Society after the program was completed. It is from the American District Steam Company, which is an invitation to visit their plant at North Tonawanda.

According to our usual procedure it is not customary for the Secretary to make any detailed report at the semi-annual meet-

ing. However, it may not be amiss to state at this time that during the past few weeks we have been busy on the publication of the proceedings of the Society for last year, and we hope to have those from the printer within probably three or four weeks, if we can depend upon his promise, and they will be immediately sent to all the members who are in good standing at that time. It is our intention, also, to see if we cannot make a record by publishing the proceedings of the current year and having them in the hands of the members not later than December of this year. To do that we will have to ask the coöperation of the members who have been good enough to prepare papers for us or who will take part in the discussion. Immediately after this meeting, or as soon as we receive the stenographer's transcript of the proceedings, the discussion will be sent to the various members for their revision. If they will be good enough to see that their discussion is revised promptly and returned to the Secretary's office it will facilitate matters greatly and insure the proceedings being in the hands of members at an early date.

During the last year the Council has seen fit to take steps to prepare or rather to make way for a more wide distribution of the proceedings of the Society, and, according to the vote of the Council, we have placed in the hands of the technical publishers of books throughout the country our volumes of proceedings for sale. There is quite a number of these volumes on hand in the Society's office, and, of course, it will help matters if we could get those moving. And we are going to try and have the technical book publishers push the sale of these books. which will bring an increased revenue.

There is one other matter that I had intended to speak about, and, as the President has very kindly spoken of it, I do not know that I should say very much about it—that is on the collection of dues. I do not know whether I am open to criticism for writing some letters which I have to some members during the past year who have been somewhat in arrears. A short time ago we discussed in the Council the question of what action we should take with members who would not respond to requests for dues. I finally sent out a request to have the members express their opinion on what we should do with members who do not pay their dues promptly. I asked what we should do with members who are in arrears for dues for two years or

more, and what we should do with those who are in arrears for one year. After canvassing the votes or expressions of opinion which came from members, I found that 98 per cent. of the members voting are in favor of dropping all those who do not pay at the end of two years, and 85 per cent. in favor of dropping members who did not pay their dues at the end of one year. This, of course, will be placed before the Council at its next meeting, and I imagine will be taken as mandatory.

As a matter of economy the dues should be paid promptly. We send out a monthly statement to the members who do not pay their dues. That means that it takes 2.4 per cent. of the dues to collect a member's dues who does not pay till December. This year we have spent something like $32 extra on printing and postage, trying to collect dues, so far. Of course, if we add 50 per cent. to that we have it close on to $50 by the end of the year, and I would urgently request that those who are in arrears for this year would do so, because it would lighten the work of the Secretary and give him a chance to attend to some other things that are greatly needed.

Another thing that I would like to speak about and to ask the coöperation of the members, and that is, on the work of the committees. Probably, if there is one thing that the Society needs more at the present time than anything else, it is to have on file in its office information on certain subjects. If we had in our possession this last year a model compulsory ventilation bill, we could have used it in five or six different places. I know the question of ventilation is coming up in Delaware next year, and if we had a model compulsory ventilation bill, it would help the Society a great deal in that direction.

President Hale: We will continue the program by calling upon the Chapters for their communications. The Illinois Chapter, being the oldest one of the organizations, we will call upon them first.

Mr. W. L. Bronaugh reads report of the Illinois Chapter.

REPORT OF ILLINOIS CHAPTER.

The Illinois Chapter wishes to report that its membership at the present time consists of 37 full members, 10 associate members, and 2 junior members.

We have added to our rolls this year nine new members, and three were dropped.

It has been the practice of the Illinois Chapter, for the past two years, for the Board of Governors to assign a topic for discussion for each of the monthly meetings—at the beginning of the season—and a committee of three is appointed to have charge of preparing the subject-matter for discussion, etc., for the evening to which they have been assigned. During the past year, these committees have seen fit to bring in outside talent on four different occasions.

The principal speaker of the November meeting was Doctor Hill. This meeting was an open meeting, and we were honored by having present President Hale, as a guest of the Chapter. In addition thereto, the Chapter entertained fourteen other guests.

The December meeting was devoted to a talk by Mr. Busey on air washing and humidifying.

The January meeting was addressed by William M. Jewell and F. S. Dunham, who gave a great deal of interesting and valuable information on water purification and filtration for boiler and house service.

The February meeting brought forth a paper by Mr. H. M. Hart, which is being presented to this semi-annual meeting of the parent society.

At the March meeting, Mr. J. W. Shepard of the Chicago Normal School, Chicago, was the principal speaker, reporting on the work done by the Chicago Ventilation Commission of the experimental plant of the Normal School.

At the April meeting Mr. August Kehm was the principal speaker, and described in detail an industrial plant, consisting of a railroad terminal and round-house, repair-shop, etc., describing the details of design and construction and the result obtained therefrom.

At the May meeting a very heated discussion was brought out over the topic of the "Commercial Position of the Heating and Ventilating Engineer." This was thoroughly indulged in from all angles—that of consulting engineer, contracting engineer, and specialty engineer. This topic was suggested with a view of determining and securing the interest of the engineers who have not identified themselves with the Society's work.

The Illinois Chapter has appointed a committee which is coöperating with a committee appointed by the Governor, for revision of the Building Code for the purpose of procuring compulsory ventilation laws.

The average attendance at the meetings was twenty.

The Chapter has contributed financially to the expense of maintaining the Chicago Ventilation Commission, which is doing excellent work in coöperation with the Department of Health, and we believe is making its activities felt to the development of the heating and ventilation profession.

Also regular meetings of the Board of Governors are held, and the Chapter is in a thoroughly healthy condition.

Respectfully submitted,

W. L. BRONAUGH,

Secretary, Illinois Chapter.

President Hale: You have heard the report from the Chapter of Illinois. Any comments to be made? Otherwise we will accept it and place it upon our records. We will hear from the New York Chapter. The Secretary is not here. The report will be read by Secretary Scott.

REPORT OF NEW YORK CHAPTER.

The New York Chapter of the American Society of Heating and Ventilating Engineers made a report at the annual meeting in January covering the months of October, November, December and January. It will, therefore, only be necessary to record the meetings of the following months.

The February meeting was held on the 18th of the month in the Engineering Societies Building. At this meeting Mr. Donnelly read a report to the Committee on Investigation of fees for professional engineering services. It was decided to refer this matter to the Board of Governors, who were instructed to report at the next meeting.

President McCann appointed the following committee on tests: Ralph C. Taggart, chairman; J. A. Donnelly, W. H. McKiever, W. S. Timmis and Conway Kiewitz.

Mr. Timmis gave a talk on "Factory Ventilation in Loft Buildings."

It was voted at this meeting to place before the members an amendment to change the meeting night of the Chapter from the third Tuesday of the month to the third Monday of the month, the Board of Governors having the power at any time

when it seems expedient to substitute some night other than the one arranged.

The March meeting was held the 17th of the month. The secretary announced the deaths of two of the Chapter members, Dr. J. S. Billings, of New York, an honorary member, who died on March 10, and J. A. Payne, of Bayonne, N. J., who died on March 3.

The Committee on Tests of the New York Chapter made a report in which was included the following:

"*Resolved:* That the Committee on Tests recommends that the New York Chapter of the American Society of Heating and Ventilating Engineers, through the trade press, invite all manufacturers of heating and ventilating apparatus and appliances, as well as all engineers, technical institutions, etc., to submit data covering any tests of heating and ventilating apparatus and appliances that they may have made, for compilation and submission to the Society. Full details concerning all tests and the conditions under which they are made should be included." Communications should be addressed to "The Committee on Tests, New York Chapter, American Society of Heating and Ventilating Engineers, 29 W. 39th St., New York."

It was voted that this report should be accepted.

The secretary announced that, in accordance with the vote of the members the meeting night of the Chapter had been changed from the third Tuesday of the month to the third Monday.

The subject of the evening was a talk on "Removing Steam from Dye Houses," and "Heating and Ventilation of the New York Post-office," by Mr. C. L. Bulkeley. The talks were illustrated by the use of several lantern slides.

The April meeting of the Chapter was held on the 21st day of the month. Mr. J. A. Donnelly submitted the report to the Committee on Tests. This report was accepted and placed on file. President McCann announced the following nominating committee: Frank T. Chapman, chairman; Frank K. Chew, G. W. Knight, E. J. Treat, C. E. Scott.

President McCann appointed W. M. MacKay and H. J. Barron to represent the Chapter at the memorial services held in honor of Dr. J. S. Billings. Wallace Goodnow read a paper on "Factory Ventilation," which was illustrated by lantern slides.

The work of the year was concluded by an elaborate dinner

in May, which was held in the Engineers Club. The dinner was a success in every way, 143 members and guests being present.

The Board of Governors have held numerous meetings during the year, which have been very well attended.

JOSEPH GRAHAM,
Secretary.

President Hale: Any remarks to be made in connection with this report? If not, it will be placed on record as a report from the New York Chapter.

The Massachusetts Chapter will report if a member of that Chapter is present.

REPORT OF MASSACHUSETTS CHAPTER.

Read by Secretary Scott.

At the time of making up the annual report, in December last, the Massachusetts Chapter had under advisement the preparation of a bill for the separation of heating and ventilating contracts from general building contracts, to be presented to the Legislature of Massachusetts, and the Chapter is still following up the question of getting such a law passed in the State as soon as such is possible. The Chapter has met each month and has had several discussions in regard to the standards for ventilating motion picture show places.

They also had an extensive discussion on the defects in the manufacture of wall radiators, trying to bring out the questions of such defects, with a view to having the manufacturers correct them. They also have had several discussions in regard to humidifying air in silk mills, and in these discussions the fact was brought out that no contagious diseases had been detected among the employees of the mills where such air conditioning was put into effect.

The Chapter has arranged for a summer outing for its members as a means of keeping the interest of the members during the summer months when no regular meetings are held.

Respectfully submitted,

J. W. H. MYRICK.

President Hale: Since the last meeting there has been an election for new members, which has just come in, and the Sec-

retary will report on those who have been elected to the membership since January.

Secretary Scott: The ballots were canvassed about the last week in June, and show the following full members elected:

Members: Clinton E. Beery, Virgil L. Brooks, Charles W. Christian, E. J. Claffy, Frank J. Douglass, F. R. Ellis, Milton W. Franklin, M. D., Charles A. Fuller, F. E. Giesecke, H. G. Issertell, August A. Kieb, William M. Kingsbury, W. S. Koithan, George A. MacKenzie, Thomas F. McCoy, C. T. Morse, Arthur K. Ohmes, S. H. Pool, R. W. Pryor, Jr., Eugene R. Stone, William W. Underhill, James D. White.

Associate; William E. Marquam, Thomas Wilson, G. A. Yokom, J. B. Collins, Roswell L. Douglass, Louis Helmer.

President Hale: The various committees are expected to make an interim report at this time and they will be called upon in the order in which we have them on our records. The committee appointed to recommend a code for testing house-heating boilers, of which Mr. E. A. May is chairman, will be heard now.

Mr. May reads report of Committee to Recommend a Code for Testing House-heating Boilers, adding:

I presume if the manufacturers' catalogues were all examined we would probably find that the depth of fuel in most of them is something about 16 inches, and we all know that it requires about a three-inch bed of hard coal to give a rekindling charge. Therefore, in arriving at the 20 per cent. those facts were taken into account. I simply insert that here because nothing is said in the paper.

On motion the report was ordered to be printed for final presentation at the annual meeting, January, 1914.

President Hale: We will hear from the chairman of the Committee on Standard Outside Minimum Weather Temperatures, Mr. Bolton.

Mr. Bolton: I can only report progress. The question has involved considerable difficulty in securing information of sufficiently comprehensive character to give us a basis to work upon. I am engaged in a year's test of conditions in New York City, which will be completed prior to the next convention in January, and it is my hope then to be able to present something that will be of service. Standardization of weather conditions is as difficult as the attempt to forecast what the weather will be the day

after to-morrow, and neither the Weather Bureau nor anybody else seems to know very much about it. We need coöperation by the Weather Bureau at Washington, but so far we have not been able to get sufficient pull to make that effective. I report progress.

President Hale: With your permission we will pass the complete report of this committee on to the January meeting. The next on the list is the Committee on Tests, of which Prof. L. A. Harding is chairman. Mr. Soule, as a member of that committee, probably has a report to make on the last year's work and what progress is being made.

Mr. Soule: I have had no correspondence with the chairman. My individual work has been in connection with fan blast tests in the Bureau of Thermal Research. This will be illustrated to-morrow. Possibly Mr. Donnelly has something he would like to tell us about.

Mr. Donnelly: Mr. President, the only thing I have to say is that I received a letter from one of our members, Mr. Nelson S. Thompson, Washington, stating the architect's office is sending a number of matters to the Bureau of Standards for tests. He is sending some valves there for tests. It seems perhaps it might lead to an opportunity for the Society's Committee on Tests to get the Bureau of Standards interested. I think perhaps it might be possible to get the Bureau of Standards to test different heights and widths and spacing of radiators. I might say that the Committee on Tests in New York have been working and asking some radiator concerns to give the efficiencies of the different forms of direct radiators. We have not been very successful so far. We are asking the committee to write to different radiator manufacturers and ask them what their different heights and styles of radiators will do. If there is a wide demand for information of this character I think we will get it. If not it may promote tests along these lines until we do get it. I believe the time must shortly come when a man who wishes to use a high radiator, a wide one or a narrow one, can get the coefficient of that radiator. I think it is something of a disgrace that we have not got it now. I think a Society as old as this is, and with as great a number of members as we have, is entitled to such information, and I do hope that the Committee on Tests, through the coöperation of the manufacturers, will get after

such things as that, so that we can go to our publications and get our coefficients that we must have to figure anything intelligently.

President Hale: The remarks made will be brought to the attention of the Committee on Tests, with the suggestion that they endeavor to get just such information as Mr. Donnelly suggests.

Heating Guarantees is the subject of another committee, of which Mr. William M. Mackay is chairman. It might be well to state here that unfortunately Mr. Mackay is absent from this meeting, this being the first meeting of the Society that he has not attended, and due to the fact that he has lost a brother and is in Montreal on a sad mission. We will ask any of the other members of the committee, of whom Mr. Taggart is present, have you any report to make as a member of the Heating Guarantee Committee?

Mr. Taggart: It seems to me that there are many lines along which tests should be made, which are very important to the Society. I know the Committee on Tests of the New York Chapter has asked certain colleges if they could not make some of these tests, and, although a favorable answer was received from some of the colleges, little progress has as yet been made. The question, for instance, of the drop in pressure of steam through elbows has not been taken up and tested as it should be, and the question as to the velocity of steam through pipes is a thing also where a great deal more work should be done. These are only examples, however, for there are many fundamental questions in connection with both heating and ventilation where additional experimentation and analysis are both necessary and desirable. If we can coöperate, that is, if we can get the colleges and manufacturing institutions and others who are interested to work with us in connection with these matters, we can make a more rapid advance than we have been able to do without this coördination of effort.

President Hale: Mr. Taggart's remarks are appreciated and are a part of the record, and we will take consideration of them at the time the matter is brought before the Council. The Committee on Guarantees was requested at the annual meeting to prepare a model law, and that was placed in the hands of Mr.

Mackay, who undoubtedly has made some progress, but unfortunately, is unable to report at this time.

"Schoolroom Ventilation" is the topic of a report which we have been looking for to-day from a committee of which Mr. Cooper, of Boston, is the chairman. If Mr. Cooper is not here, I will ask if anyone else is here who is a member of that committee? It consists of Mr. Cooper, Mr. Kimball, Mr. Eveleth, Mr. Feldman and Mr. Whitten. As there is no report, and none of the members of the committee are present, we will pass that, and hear the report from the chairman of the Committee on Compulsory Legislation, Professor Hoffman.

Professor Hoffman: Some splendid work was done last winter looking forward to laws for the compulsory ventilation of schools, auditoriums and the like, but in no place probably was the complete success established. In New York, Cleveland, Chicago, Milwaukee and Indianapolis, and a number of places, the efforts were very strenuous. Some were fairly well received. Others only moderately so. I think it is only fair to say that we believe the general tendency is upward. There have been a good many influences working against the enactment of such laws in some of the States. Some of the efforts we made for such laws were wholly cast out, while in others a compromise was effected. I am pleased to say to you that where the fight was the hottest we have found the members of this Society in the front rank, which I think is very commendatory. As an interim report I will make for this committee merely a verbal one, and say that we are still working upon the draft of the model law. That has been with us and before our committee for a year and a half. We have it, I believe, in better form than it has been any time yet, but, even as it is, this committee is not wholly satisfied. I am sure that the report, if presented to the Society in writing at this time, would not pass unanimously. We do not agree on some of the fundamental principles, and it is necessary to continue. We propose to take up the thing and thrash it out again this fall, and it is our purpose, if such can be carried out, to send to every member of the Society, through our Secretary, a *questionnaire* to have certain points brought out, and we hope that every member who receives one of these *questionnaires* will reply to all the questions. It is to be desired that when this law or model law should come before us as a Society that we would be

fairly well agreed and that points of objection be thrashed out before it is brought before us. I merely want to report to you progress, and to say that in that progress we have not been unmindful of the fact that this has been an important matter. I am satisfied that if this Society could have been a unit on such a law in the past year that a number of States would have done something, but did nothing, and some of them who did only fairly well would have done better. But when there is dissension at home there surely can be little hope of great results among those who look to us to take the lead. So I am hoping that every member will give us his undivided interest and a little time from your otherwise busy occupations to think the matter over and give us the benefit of your advice at the time when we write to you for it, because we are surely going to give you an opportunity in a very short time.

President Hale: In connection with this compulsory legislation, I would state that there are a number of committees—subcommittees in the various States, also, who are looking after the local interests, and the Secretary reports that they are very active in Delaware, and probably an attempt will be made next year to put a bill through. It is to be hoped that by that time we will get something that can be put before the legislators there and those interested in the bill that will make it possible to get something through. For some years the attempt has been made to accomplish something in the State of Illinois, but one condition after the other has arisen, so that up to the present time the Chair has no knowledge of anything actually being put before the legislature so that it could be considered as a bill, although some years ago a bill was presented and defeated. Mr. Lewis is chairman of the Illinois committee; he may have some remarks to make that will be of interest to us. . . . Evidently from the shake of Mr. Lewis' head I judge there is nothing to report. In Indiana the committee is in charge of Mr. Weinshank, chairman, who probably has some remarks to make.

Mr. Weinshank: We had a three-cornered fight at the last convention of the legislature in Indiana. We have a law in Indiana now, and we had one two years ago, but, owing to the fact that the legislators did not know what was right and what was wrong, and did not have data from anyone to tell them which was right and which was wrong, the law as passed is a make-

shift or a foundation toward a good law. At the last session of the legislature we attempted to pass a bill and the bill was "loaded." That is, we knew it was going to be shaved, and the bill as presented was so broad that we expected it to be cut down, and were prepared to be satisfied with what was left. Owing to a difficult situation that developed we only got a partial law, but it is broad enough so that the State Board of Health can so interpret it to make it a good law if they want to. You may say we have no law, and at the same time you can say we have a good one, because the requirements are left entirely to the State Board of Health. The only specific requirement that we have in our law is that each school room must have 30 cubic feet of air per minute for each seat, and 225 cubic feet of space. The State Board of Health must enforce that law, whether direct, indirect, or blast system of heating is used, or a combination of the two. But the law does not give the State Board of Health the power to prosecute the commissioners. The result is that, while the State law requires a fine of the commissioners or contractors, there is no law to enforce it.

But had we, at the last session of the legislature, a model law endorsed by this Society, there is no question but it would have been adopted. But when I was called before the Judiciary Committee of the Legislature to explain to them the three different bills before the legislature, one of the legislators asked me, "What do you make out of it?" and I told him I was disinterested, and he said: "What do you come here for?" I told him that I was invited by a member. As a rule the legislators look upon anyone who comes before them asking for the passage of a bill as though he has some interest. If I had a model law or a model ventilating law, and laid it down before them and told them, "Gentlemen, this is a law which has been drawn by the American Society of Heating and Ventilating Engineers and endorsed by them," that would have been all that was necessary. I will say, further, that if the Society does pass a model law or endorse a model law we will have no trouble in passing it in Indiana.

President Hale: It is evident from the remarks that there is nothing for the members to pass upon as to the adoption or acceptance of reports, these all being interim reports. We will, therefore, pass on to consideration of other committees. Last

year a committee was appointed and reported a method of testing air velocities by the use of an anemometer. The question came up at that time as to whether or not that was to be established as a standard for testing air velocities. It was clearly shown that there was only one method considered for determining air velocities, and that was by use of the anemometer. Consequently, another committee has been appointed to recommend a code for testing air velocities by the use of the Pitot Tube, and that committee consists of J. I. Lyle, Chairman; S. R. Lewis, W. L. Bronaugh, Frank L. Busey and J. D. Hoffman. However, this committee has only recently been appointed, and has not been able to get together sufficiently to make a report. We will not, therefore, look for a report to-day, but Mr. Lyle may this afternoon make some remarks on the subject, so that we will get some idea of what they are driving at.

A committee has also been appointed to represent the Society at the National Conservation Society Congress to be held in August, of which Henry Adams is the Chairman, and N. S. Thompson and M. S. Cooley are the other members. They will represent us at that time and report in January as to the finding of the Congress, if it relates to anything that we are interested in.

A committee has also been appointed to represent the Society at the International Congress on Hygiene, of which F. I. Cooper is Chairman, N. L. Patterson, S. R. Lewis, D. D. Kimball and C. B. J. Snyder are members. That takes place next month at Buffalo, and we will probably have a report from them in January, which without doubt will be extremely interesting and profitable.

There are no further committee reports as far as the records show. We will go on to the subject of old business unfinished. There being no old business unfinished to be attended to at this time, we will call the next item of new business, under which heading Mr. Donnelly has some very important remarks to make in reference to our constitution and by-laws.

Mr. Donnelly: Mr. President, the questions on our Articles of Incorporation and Constitution came up in the Council just prior to the January meeting, and I consulted an attorney in New York regarding some features of it. It has been discussed very briefly in the Council since then, the Council never having had time to take it up in detail. I am going to allude briefly to it, and

not take it up in detail, because of the limited time. It is absolutely necessary for us to do quite a number of things. For instance, our Articles of Incorporation in New York State are now in the exact condition they were when we were first incorporated. The objects of the Society are set forth in those articles of incorporation. Those same objects were in our Constitution, if I have looked over the back numbers correctly, until our last change, when they were put in in much briefer form. Now, that is not possible. Nothing which is in the Articles of Incorporation can afterward be taken out. If you wish to cut the name of the Society down you would have to reincorporate. You may add something to it, but you cannot take away from it.

The Board of Directors, as it is called in the law, we have changed from Board of Governors to Council; the attorney whom I have consulted advises us to call them directors; and, whatever we call them, they are in the law directors; they may be called a Council, but they are Directors. Now, the number of them in the original Articles of Incorporation, was seven; that was altered by a change in the Constitution, which did not amend the Articles of Incorporation, and by a change which made them twelve. Now, the law says that we may change the charter at any regular or special meeting of the corporation and file an amended certificate with the County Clerk, so I had our lawyer prepare a notice for calling such a meeting. That meeting will have to be held in the City of New York. It is perhaps another strange provision of the law that there is no provision for a meeting of the corporation outside of the city in which the principal office of business is located. In other words, all these summer meetings of our Society are not meetings of the corporation. We can understand that better, perhaps, when we realize that the only business that the corporation can transact at its meetings practically is to elect directors, not necessarily to elect officers, for the law does not take any recognition of the election of officers. The only other business is the listening to and receiving of reports of the Board of Directors and the different officers. The actual management of a corporation is vested so closely in the Board of Directors that motions to print different things and motions to transact different business of the Society are really not in order.

Along these lines I have prepared some amendments to the

Constitution. The first thing we want to do is to put back into the Constitution the objects to make it agree with the Articles of Incorporation. As I stated, we have no choice in that matter. The law says you can adopt such other by-laws or constitution as do not disagree with the law of the State or with the Articles of Incorporation. Under the Articles of Incorporation it seems necessary to change it.

The Attorney-General was asked whether meetings could be held outside the city, and he replied they could not. It goes on to say that the annual meeting shall begin on the third Tuesday in January of each year; that is another thing in which we have been remiss. The Constitution must state the exact date on which the annual meeting must be held. The law is very jealous of the exact time of notice of any meeting to be given to any member at which he is entitled to vote; therefore, the exact date must be specified.

Special meetings of the corporation seem to be provided, for only one purpose, practically no other use in calling a meeting excepting perhaps for amendment to the Articles of Incorporation, amendments to the constitution, something of that nature. Now, following along that line, it seems best to call the summer meetings professional sessions, and that the annual meeting be the only meeting of the corporation, and so I have suggested the following: "Professional sessions for the reading and discussion of papers shall be called at least twice a year." That makes it mandatory to meet twice a year; of course if that does not seem necessary we need not, but it seems to me that we ought to hold such sessions; I think that we can afford to hold professional sessions for such purposes at least twice a year. By a provision of the law every member is entitled to vote by proxy, and in order to advise our members of that fact I think it is only fair to put it into our constitution.

I have also recommended the change of Council to Directors, so that we will not have any confusion in it. The latter part suggests a way in which we may use a Council in other purposes than for the business of the corporation, but the business of the corporation should be done by the directors.

In the election of members there is a slight change. The method of electing honorary members seems to be, put them out for mail ballot. This seems inadvisable, as the election of

an honorary member can only come through the unanimous presentation of a name by the Board of Directors. It would seem to be not advisable to have the membership in any degree throw back that request or an invitation to a man to join as an honorary member. It seems that we must trust to the discretion of our Board of Directors. For instance, if they desired to so elect a man prominent in the heating or engineering profession, they must ask him if he is agreeable before they can bring his name up, and then it would seem to me that it would be extremely humiliating to such a man to be told that he had been rejected after he had been recommended by the Board of Directors.

The secretary called our attention to our method of electing members, that there is no way of refusing to vote for a man because you were unacquainted with him. Our former method was that you could write "Yes" or "No" after a man's name and if you did not feel like voting you did not have to. Our Secretary was rather afraid that some members would cross a man's name off on this last ballot. It seems to me as if there should be no by-laws to make a man vote either "Yes" or "No." It seems as if a member should have a right to say "I do not like to vote on that man; I don't know him at all."

In regard to the election of directors and the terms of their offices. The Constitution has a provision that the last President would automatically become a member of the Board of Directors; that cannot be done legally. The Mechanical Engineers have fallen into even a worse mistake; they have the last five surviving presidents as members of the Board of Directors. The law is definite in stating that you must elect your directors each year. There is only the provision that you may divide your directors into classes; you may elect three directors a year, or six directors, or some such proceeding. But it is not possible to elect a man as President and as a director for two years. No such proceeding could be done legally. I may say, too, that it seems to me that the necessity of having directors is that if we wish to have a legal action or sue anybody or defend an action, we have got to have a legally elected Board of Directors.

You must elect all of them each year or else you will have to

divide them into classes and then allow the directors themselves to choose the President.

In Section 4 it seems mandatory to the Secretary to send out a list of our members each year and the Board of Directors seems to think that it would be a good thing to have that optional with the directors.

In Section 6 of Art. 6 there is inserted a clause which requires a presentation of the report of the Society. The law calls for this so that in case we are sued or any action brought against us a visit can be made to the Society's office and there in the proceedings each year is a record of our property and the amount of it. This is necessary under the law so that an attachment can be made upon it by the Sheriff; we hope there will not be such a necessity. But if the law says so, we think it just as easy to comply with the law. In Article 7 it will be necessary then to insert "The President or Vice-President shall not be eligible to re-election."

In Section 7 the report of the Nominating Committee was to come in 60 days before the election. Last year it was found that no time elapsed for the independent nominations and so it has been suggested that 90 days should elapse and thus give 30 days for independent nominations.

In regard to the election of directors the attorney whom I consulted advised me that the election of directors by a mail ballot as we do it at present, is not legal. The only way that anyone can vote at an annual meeting is in person or by proxy.

There seems to be a considerable desire on the part of the members for a number of years to have more or less of the business affairs of the Society conducted by the meeting, for instance such motions as have been made here to-day, to print different things, etc. I think it may be possible to have it so drawn up by someone looking over the matter with more legal insight than I have, to separate the business of the Society from the professional work of the Society. It would seem as if the accepting of different standards and the revising of them for publication, the exact wording of them, the professional standing of members and the reports of Committee work and then if we had any reading of papers and such and such matters, could be put into the hands of the meetings. Whether it is advisable to do it or not I don't know; probably not. It seems to me that the Board

of Directors could take charge of this professional work as well as the business. But it is a fact that the Board of Directors can buy and sell and do the business of the Society. When these questions came up and this necessity seemed to be before the Board of Directors, they authorized me to consult an attorney in regard to it and the question of compensation was raised, and it seemed to them that $25 was about right and I thought I could get it done for $25. After going over it we thought we might be able to get this attorney as an associate member of the Society and the Board of Directors have discussed the matter informally both in New York and here and it seems to be their feeling that it would be a good thing to have a lawyer as a member. This would cancel, take care of a $25 charge, $15 for initiation and $10 for dues. And we might retain him as counsel; whether we would be any better off in appointing a man as legal counsel or rather to do it informally, I don't know, and perhaps Mr. Hale can tell you more about how the Council has gone over this thing of getting a lawyer in. We certainly learned from Mr. Weinshank's remarks and some of the others that we could use some legal adviser in getting such work out of him as we could. I know that this particular man is a pretty good after-dinner speaker and has some lectures which would interest us. For instance, he has something upon "The Sources of our Law" and he has prepared one on Professional Standards.

President Hale: It is very evident from the report which Mr. Donnelly has made that according to the law we are not legally in session. However, we will go on on the assumption that conditions are just as they were in the past. I would like to state that the Council did discuss this question carefully and decided that it was of sufficient importance to have Mr. Donnelly as a committee of one to investigate the subject so that it can be presented to you to-day. You have heard his remarks. It is very evident that something should be done about getting on a legal basis and revising our constitution and by-laws. The Chair would like to hear the remarks of those present in reference to the subject.

Mr. Davis: It would seem to me that it is a matter that should be referred to the Council and for the Council's recommendation to the Society.

Mr. Donnelly: I did not state my conclusion in this, and my

advice would be the necessity of calling a special meeting of the Society in the Fall sometime, a meeting to which we could present these amendments to the constitution, and I think these amendments to the constitution should be really presented at this meeting and voted upon so that we could send them out by letter ballot in accordance with our present constitution. We must either do that or print them and vote upon them in the Fall. We would have to hold that special meeting in order to change the number of our directors and we cannot hold that meeting unless in the City of New York. As I say, any member can send his proxy to any other member giving him directions to vote for him, specifically or generally upon questions that come up before the meeting. But it seems to me that the preliminary vote may be taken at this meeting or it may be taken at the Fall meeting and then submit them to letter ballot after that has passed. I really believe we will have to have a special meeting in the Fall so that we can get matters in shape.

Mr. Lewis: It is in order, then, to have the question of these amendments printed and sent out for a ballot prior to the special meeting; is that the idea?

President Hale: That is the thought.

Mr. Donnelly: A motion would be necessary, really I don't know the language of the constitution, to get the subject under discussion, the amendments of the constitution must be proposed and you must vote as to whether we will accept them or not. As I say, it might be well to do this at this meeting; I don't know whether it would be necessary to make that motion over again at the Special Meeting. I might say in regard to Mr. Davis' suggestion to refer the matter to the Board of Directors, that does not seem advisable. They should originate with the members. The Board of Directors in the revision of the constitution should keep their hands off. The Board of Directors have their duties to do and their duties are not to amend the constitution. They may make recommendations, but even then the recommendations should come from them as members. Each member of the Society is just like a sovereign voter and he should be allowed to cast his ballot unbiased.

Mr. Capron: To bring this matter properly before the house I move the adoption of these amendments.

Mr. Davis: We are working under the constitution and by-

laws as they stand at the present time and we cannot adopt anything except in regular form. Now, what is that regular form in regard to the change of by-laws? We have to follow that, whatever it is. We cannot change the by-laws except in the regular way.

Mr. Capron: My only reason for bringing up the motion was to get the matter before the meeting. I withdraw the motion and move you that this body approve these proposed amendments to the constitution.

A Member: Second the motion.

President Hale: Any further remarks?

(The motion was put and carried.)

President Hale: The recommendations have been approved by the Society, by those present here. The matter will come up in due form. The members will be notified by the Secretary.

In the Council meetings there has been discussed the question of going over the records of our Society and appointing committees for the revising of the various standards which have been adopted from time to time so as to bring them all up to date. The Secretary has made some investigation as to what standards have been adopted and what is still to be done and the Chair will appoint committees for the purpose of bringing these standards up to date, and those committees are to report at the January meeting, so that we can get a final action of the Society on all of the standards that we are ready to consider. If there is no further unfinished business or new business, we will proceed with the first paper of the day, entitled "Time Analysis in Starting Heating Apparatus," by Ralph C. Taggart, New York.

Mr. Taggart: It is so late that I am not going to read the paper but only make some remarks about it. May I not make a motion to adjourn?

President Hale: It is now 12:30; the next session is at 2 o'clock. The next session will be a long one. There are three papers this afternoon which will rather fill our afternoon to the dinner hour. However, that is for you to decide. You have heard the motion that we adjourn until the afternoon at 2 o'clock; do I hear a second? (A member seconds the motion.) Motion carried.

THURSDAY AFTERNOON SESSION

(The meeting was called to order at 2:30 o'clock.)

President Hale: As stated this morning, we will continue the meeting by the reading of papers, two of which were on the program for this morning. The papers will not be read complete but will be read in extracts only, the author explaining the various points which he wishes to bring particularly to the attention of the members, and every one present, guests as well as members, are invited to join in the discussion. The discussion will be as in the January meeting; each member or guest who wishes to ask a question or make remarks will do so, the author of the paper making a record of the questions and answering them all at the one time, this in order to prevent a discussion on the floor which takes up a great length of time. We are rather limited in time for this session because of the fact that we have five papers which must be considered, and it is to be hoped that the questions and statements will be to the point and without taking too much time. We will ask Mr. Taggart to read his paper entitled "Time Analysis in Starting Heating Apparatus" by extract, and as I stated before the questions to be asked will be noted by Mr. Taggart and answered at one time. You will find in the back of each of the papers a number of blank sheets which were put there for the purpose of making notations, so that you may keep your records in connection with the paper itself rather than by putting it on a separate sheet which may be lost.

Mr. Taggart reads and comments on his paper and afterward it was discussed by Mr. Cooley and Mr. Verner, who were answered by Mr. Taggart.

President Hale: We will listen to the paper by Mr. Hart entitled "Expense of Operating Heating and Ventilating Plants."

Mr. Hart: The President has asked that we discuss briefly a few points in these papers, and not read them *in toto;* I think, however, that it might be advisable to read in detail the methods of computing the cost of operation, which, as stated in the preamble here, have been divided into several classes of buildings. No doubt these methods are familiar to most of you.

Mr. Hart reads and discusses paper and the discussion was

continued by Mr. Lynd, Mr. Weinshank, Mr. Bolton, Mr. May, Mr. MacDonald, and President Hale.

President Hale: The next paper for the session is by Professor Bass. Unfortunately the Professor has not reached Buffalo or is not at the meeting, and in deference to him, inasmuch as he expects to be here, we will put that aside temporarily until he has an opportunity to be here and discuss it on the floor. Mr. Busey, if he is present, will be called upon to read his paper. He not being here we will temporarily refer to a topic or two of discussion so as to take up the time without loss. The first topic of discussion is Ventilation and the Open Window. This is only intended to give an opportunity to keep busy while we are awaiting Mr. Busey's arrival. Mr. Cooley has written a topic for discussion of this subject—Ventilation and the Open Window—and just went out to get a copy of the paper. He will start the discussion. Mr. Cooley, will you start that discussion on Ventilation and the Open Window?

Mr. Cooley: I do not know whether the members have had a chance to read this. Do you think it will be necessary to read it all?

President Hale: I would not read it all. You might state that this was written for last January's discussion, and it was decided to bring it up for this meeting. You have undoubtedly all read the discussion on this subject.

(Mr. Cooley reads by extract.)

President Hale: Do the members wish to join in this discussion of Ventilation by Open Windows? It is before you. As there is no response I judge that no one wishes to make any further remarks on this subject. I will now call upon the Committee appointed to make recommendations as to a standard for the use of the Pitot Tube in the Measurement of Air Velocities. I understand this Committee has been together this noon and may have some preliminary remarks to make although it is not expected that they will make a full report.

Mr. Lyle: The Committee had a very satisfactory meeting today but I have not a report ready. We have adopted a report, I imagine, in a form that will stand. That was going to the stenographer and we expect to have a copy for the different members to sign to-morrow morning. We have made some progress but I am not ready to report.

President Hale: Will you be ready to report at the Saturday morning meeting?

Mr. Lyle: I think so.

President Hale: We will make a note of that. Unfortunately Mr. Cooley's paper "Chart for Determining Size of Pipe for Gravity Hot-Water Heating Systems" has not arrived. It is on its way, started from New York yesterday. As soon as it arrives we will call upon Mr. Cooley to read it. I am pleased to state that Mr. Busey has come into the room and I will call upon him to read his paper, by extract only.

Mr. Busey reads paper.

President Hale: The paper is now before you for discussion and further remarks by all, visitors and guests, as well as members. There are several members here who have, without doubt, had great experience in just such matters as this, but perhaps have not made tests with the Venturi type of elbow, though no doubt they could give us information of value if they would be willing to express themselves.

Professor Hoffman: I was rather hoping that Mr. Busey might have carried this a little further and tried it upon square piping and square elbows—that is, square in section or rectangular in section, I should say, and then in addition to the long curve they put in what is commonly known as the "splitter" to see what effect the splitter in the air conduit would have in reducing the air pressure. I had considerable experience in running some of those tests myself this winter. I think they were not conclusive at all, but they proved to me that the splitter placed in a rectangular section elbow was a decided advantage in reducing the pressure and increasing the amount of air put through the tube.

President Hale: Are there any members who have other questions to ask Mr. Busey about his experiments? I see a rather animated discussion between three gentlemen who have had considerable experience, but they do not seem anxious to get on the floor. Must we pass on to the other subjects without making any further remarks about the experiments?

Unfortunately Prof. Bass is not here, and, in the absence of Prof. Bass, that the paper may come up now and be discussed while we are all present, Mr. Samuel R. Lewis will read Profes-

sor Bass' paper, entitled, "Experiment in School Room Ventilation with Reduced Air Supply Through Individual Ducts."

(Vice-President Capron here took the Chair.)

(Mr. Lewis reads Professor Bass' paper by extract.)

Mr. Lewis: Since this test was made, after the beginning of the test carried on under the direction of Professor Shepard of Chicago, I suggested to him that a written discussion on Professor Bass' paper might be desirable, and, if you have no objections, I will read Professor Shepard's discussion.

This was followed by remarks by Mr. Hart, Professor Hoffman, Mr. Lewis, Mr. Carrier, Dr. Hill, Mr. Taggart, Mr. Weinshank, Mr. Cooley, Mr. Scott and Mr. Capron.

Secretary Scott: May I make a suggestion? Early in the year, or rather, early in the spring, we conceived the idea that it would be advisable to gather some of the data on tests which had been conducted along the lines described in this paper by Professor Bass, by Dr. Shepard, and by Dr. McCurdy, at the Springfield Gymnasium, as has been referred to here before. I immediately wrote to a committee in Chicago, asking its members to wait upon Dr. Shepard, and to a committee of our members in Minneapolis, asking them to wait upon Professor Bass. Professor Bass, I believe, had already promised a paper to the International Congress on School Hygiene, which is to be held at Buffalo next month, but he consented to write a paper for us also. I believe Dr. Shepard had promised to write a paper for the International Congress on Hygiene. That matter was taken up by some of the Chicago members. Dr. Shepard also wrote me, and I told him that out of professional courtesy I did not see how we could ask him to give us a paper at this meeting, inasmuch as he had promised a paper to the International Congress on School Hygiene, and especially as he stated that they were going to conduct some experiments this fall, and would be glad to give us a paper at our annual meeting. Dr. McCurdy has also promised a paper to the International Hygiene Congress, thereby getting in ahead of us again, but he has also promised to give us a paper at a later date. We must remember that Professor Bass is a non-member of the Society, and that he has been requested to present this paper to us. In any motions that are made I would like to have the appreciation of the Society expressed at giving us this paper, and, if there are any changes to

be requested, I think it would be a good idea to make a motion that the paper be referred to Professor Bass with a transcript of the discussion on it this afternoon, and it may be that he will want to make some changes in it before it will become a part of our records.

Mr. Lewis: I would like to withdraw the motion that I made and substitute another motion. I move that the thanks of the Society be extended to Professor Bass for this very valuable paper, and that the Secretary be requested to write a tactful letter to Professor Bass, stating that we appreciate his courtesy in giving us this information, sending him a transcript of the discussion, asking him if, in view of this discussion, he would not be willing to modify, perhaps, some of the conclusions at which he arrived, asking him if we might be given the benefit of his future experiments, extending to him the promise of our coöperation in every possible way in aiding them in conducting these experiments.

A Member: Second the motion. (Motion put and carried.)

Chairman Capron: It is unfortunate that Professor Bass is not here to answer these questions; there is a possibility that he will be here by Saturday. If he is, you will have a chance to talk to him; if not, he will be asked to reply by letter, and his answer will appear in the transactions. We will now proceed with Mr. Cooley's paper, which has just arrived.

Mr. Cooley: This paper contains a chart, as you know, and I have been told by two or three people that the explanation in here is not sufficiently clear for them to understand how the results have been arrived at. If I could be given an opportunity to put it on the blackboard I could save very much more time.

President Hale: Mr. Chairman, it is almost 20 minutes to six. I move that we adjourn.

Motion seconded and carried. Meeting adjourned.

Saturday Morning Session.

Meeting called to order by President Hale at 9:35 o'clock.

President Hale: Unfortunately, many members have not yet come, but the time is so limited this morning we will have to start with our program, as we have three papers and a number of business matters that have to be attended to. We were most

unfortunate last year, in not having President Allen with us because of his absence in Turkey, and I am very sure you would like to hear a word from him to-day in reference to Society matters, and I will ask Professor Allen if he will sit on the platform with us this morning.

(Professor Allen takes seat on platform. Applause.)

It is not necessary for me to introduce to you Professor Allen. He probably will have a word or two to say in reference to his past connection with the Society and the future of it.

Professor Allen: Gentlemen of the Society—I have not prepared a formal address this morning, but I am glad to have the opportunity of addressing the Society for a few minutes, as I did not have the pleasure of presenting the Society with my annual address in person. I well remember the first meeting of the Society that I attended, a good many years ago, and the character of the papers presented. When the character of the papers presented at that meeting and those of to-day are compared, you realize the growth that the Society has made in the last decade. The heating and ventilating of most of our buildings about ten years ago was left very largely in the hands of the plumber and steamfitter. Many of them made no computations at all, and trusted to their experience to obtain the proper proportion of the heating plant; others used some rule of thumb. The question of the scientific development of the subject had not been considered except by a very few. Within the last ten years there has been a very marked change, which has been largely brought about by the development of the fan system of heating and ventilation. When the fan system came into use it became necessary to employ technical men to make the necessary computations and to carry out the designs. With the introduction of a large number of technical men into the heating and ventilating field there was a marked change in the character of the work done. It began to develop from the rule of thumb business into an engineering science. It is not yet a science, but it is developing rapidly. In order to formulate general laws of a scientific nature it will be necessary for the engineer to have a large amount of scientific data from which to draw general conclusions. Much of this data has been obtained by careful experiments in the last few years, but it is in the hands of the different manufacturing concerns, consulting engineers and the technical

schools. From time to time this Society has endeavored to collect this data and increase our store of information. This has been work that is fundamental in development of the heating and ventilating science, and, when sufficient data has been obtained so that general laws can be formulated covering the fundamental principles of the heating and ventilating art, then we can call heating and ventilation a science. The character of the papers that have been presented before this Society during the last two years, and the character of the papers presented to-day, begins to show this tendency to develop the heating and ventilating art into a science.

There are many things, however, that we do not know—fundamental things—take for example the science of ventilation. The physiologist has not told us how we can determine when the ventilation of a room is satisfactory. There is no definite standard by which ventilation may be said to be good or bad. There is much information needed along these lines, and this information must be obtained by the physiologist. As soon as the physiologist will tell the engineer what is necessary for satisfactory ventilation, the engineer will very soon be able to produce the results desired.

Even in so fundamental a proposition as the heat lost from a building we have very little information that will tell how to determine these losses accurately. The question of the amount of radiation to be supplied in a room to produce a given temperature is not definitely settled. We might say that the foundation and very fundamental principles of the science of heating and ventilation have not yet been definitely settled. There is much work to be done, and this Society is the best means through which this work can be done, and I look to see a great future for the Society in developing the art of heating and ventilating into the science of heating and ventilation.

I had the pleasure last year of meeting the officers of the heating and ventilating society in England, and to talk with them with regard to the situation abroad. They are very frank to admit that the American engineer has gone farther in the science of heating and ventilation than the British engineer. Of course, the necessity of heating in England is not as great as in our own country, and, as a result, there has not been as much effort made to perfect heating there as in this country, and ventilation has

not reached the same state of perfection. In England hot-water heating is almost entirely used, where a central heating plant is installed, and very little has been done in the line of steam heating. What has been done would look very crude as compared with the American plant. The English heating and ventilating engineer looks to the United States to see the latest development in our science.

In Germany there has been a great deal of stimulus given to the development of the theoretical side of heating, primarily, of course, due to the German's love of scientific investigation, and in addition to the fact that some of the German schools have been equipped with splendid experimental laboratories to obtain information along these lines. When it comes to the principle and installation of heating plants the German engineer has not reached the state of perfection that has been reached in this country. I think it is generally conceded throughout Europe that the highest state of heating and ventilating art has been reached in America, and still there is a great deal to be done. There are many fundamental points to be determined, and I look for a great future for this Society in the development of heating and ventilating as a science.

President Hale: Last year at the summer meeting in Detroit we were approached by a committee from the National District Heating Association to appoint a committee from our organization for the purpose of coöperating with them in the determining of a certain code of requirements, and, as we have with us to-day the President of the National District Heating Association, we will ask Mr. Bushnell to say a few words in reference to their organization and his desire that the two organizations should establish friendly relations and coöperate as far as possible, so as to advance the science of heating and ventilation.

Mr. Bushnell: Gentlemen of the Society—Upon the subject suggested by our President I am very glad indeed to say a few words. As you know, the National District Heating Association is working along nearly the same lines as the American Society of Heating and Ventilating Engineers, although it is, perhaps, not doing it as scientifically. The National District Heating Association lays especial stress on the practical and financial side of the heating business, while the Society of Heating and Ventilat-

ing Engineers is engaged more especially in the scientific and engineering aspects of the subject. It is especially along the engineering and theoretical lines that the heating companies will need the advice and assistance of the Society of Heating and Ventilating Engineers. In the last twenty-five years there has been a great change in the attitude of the practical mechanic and the practical business man toward educated and scientific men. I remember when I came to Chicago twenty-five years ago I found a very strong prejudice against college men. It was very hard for me to get a position at electrical engineering work, simply because of a belief that a college man was a theorist and was likely to wander off into impractical ideas on account of knowing very little about the actual requirements of the business. To-day, in the electrical business especially, there is an entire change. In Chicago the electrical companies have just organized what they call the Central Station Institute, which is an educational institution which goes into the matter of electrical and steam engineering on a scientific basis, and gives the young men who have come there a preparation of two years by actual work and the study of Central Station practice. They are given the opportunity of working in the departments of the different companies interested in the Institute, and at the same time half of each day is devoted to lectures and a study of the scientific phases of the work. A high official of the Edison Company told me, within a few months: "I want to get college men, as far as possible in our organization, because we need men that will grow." The general sentiment of the companies who are operating power plants is to keep as closely in touch as possible with the engineering and college fraternity. In Germany one reason they have made such a great advance in manufacturing is because they have kept so close to the scientific schools, and I think we in America are learning to do that more and more. It is in line with that tendency that we, as President Hale has said, thought it would be well to have a committee from both societies to be called the Educational Committee, which will take up questions on which there is a chance for diverse opinions in order to work them out on practical and scientific lines. As I understand it, that committee is to get to work this year and we hope to get good results. As Professor Allen suggested, there are a number of subjects on which we

have collected some data, but in the past our data has been insufficient. One reason why we should now get better results than ever before, is that steam meters have become generally used in the last five years. This gives us actual data upon which to figure our results, and I am hoping that in the coming year we may secure much valuable data that will help us to come a little nearer that authoritative code of rule and practice to which we are looking forward.

President Hale: We were unable to complete Thursday's program, and the paper entitled "Chart for Determining Size of Pipe for Gravity Hot-water Heating Systems," by Mr. Cooley, of Washington, has been brought up this morning as the first paper for reading and discussion. The time being limited we will be compelled to read this by title or extract, giving the author the opportunity of covering the points set forth without reading it in its entirety, and the members in discussing the paper afterward will ask their questions in such a way that the author may be able to answer them all at one time, rather than having a general discussion on the floor. The subject is open for discussion to all, members and visitors as well.

(Mr. Cooley reads paper, and explains chart on blackboard.)

The discussion was taken up by Mr. Hale, Mr. Hart, Mr. Libby, Mr. Newport, Mr. Davis, and Secretary Scott, after which Mr. Cooley replied to the several questions asked.

President Hale: We were very well pleased yesterday with the investigations made at the Institute of Thermal Research, and undoubtedly everyone was thankful for the opportunity of investigating for himself the exact method that the author of the next paper used in determining the data upon which the paper is based. We will ask Mr. Soule to read his paper on "Heat Transmission with Pipe Coils and Cast-iron Heaters under Fan Blast Conditions." The reading and comments will be the same as in the previous cases, only by extract and not in its entirety.

Mr. Soule: I would like to read just certain portions from the paper and explain in connection with other portions.

President Hale: This is undoubtedly one of the extremely interesting papers of our meeting, and the opportunity of witnessing the method of testing yesterday was such that you will

probably have many questions that you will want to ask about the records and how certain things were arrived at. To certain points attention has been called, but you will probably ask of the author additional questions. Probably Mr. Soule will be able to give you a record of the findings in the test yesterday, which will perhaps give additional information that he has not already stated. The subject is open for your discussion on the basis of the previous discussions. Mr. Soule will reply to any questions all at one time, to prevent general discussion on the floor.

Paper was discussed by Professor Allen, Dr. Hill, Mr. Brightman, Mr. McCann, Mr. Still, Mr. Donnelly, Mr. Weinshank, and they were replied to by Mr. Soule.

President Hale: With your permission we will go on to the next paper; the time is getting late. In Chicago they have done a great deal in the control of the ventilation of buildings. I believe it is the first city to appoint an Inspection Department to cover that subject, and we are very much favored to-day by having with us the chief of that department, Dr. E. Vernon Hill, of Chicago, who has very kindly consented to talk to us upon the organization and work of the Ventilation and Inspection Department of the city. Dr. Hill has brought charts with him, which he will throw upon the canvas here to show what they are aiming at, and what they hope to accomplish.

Dr. Hill: Mr. President, in correspondence with Secretary Scott, he thought that inasmuch as we were the first to take up this work in this way, it would be of interest to the Society, and possibly of value to other cities starting in the same line of work if I outlined what we were doing with regard to enforcing the ordinances covering ventilation. So I had photographs made of our card record systems and certain instruments that we are using, and slides made from these photographs. Now, I must say that I have not seen the slides myself thrown on the screen, and some of the photographs are not very good, so you will have to take them for what they are worth. It was not a case where we could select the best; we had to make slides from the photographs we had. So with that explanation I will proceed. This paper, of course, is simply a discussion of the slides which I show you and a brief summary of the ordi-

nances covering this part of the work. (Reads from paper as the lantern slides are shown.)

President Hale: I believe we should express our words of appreciation for the talk Dr. Hill has given us to-day, and also for the work done in Chicago, as it will undoubtedly be the foundation for similar work done the country over. It is gratifying to state that the paper with the lantern slides is available for the publication in our proceedings, and will be turned over, I understand, to the Publication Committee, who will take such parts of the charts and illustrations as they may think desirable to use in the 1913 proceedings.

Professor Hoffman: Mr. President, as Chairman of the Committee on Compulsory Legislation, I would like to request that the Secretary give us a copy of that for use in the work which is now just ahead of us, and I would like in addition to express a vote of thanks to Dr. Hill for his very valuable and interesting paper.

The motion was seconded and carried.

President Hale: The papers as set down upon our program have all been read and discussed. There are a number of topics for discussion, which are put there for the purpose of filling in, so as to assist the Chair in keeping things going. Before we attempt to go to them, however, there are other matters which must be taken care of. The committee appointed to report upon the standard for measuring air velocities by the use of the Pitot tube have met, and they state that they will be unable to give a definite report at this meeting. They have met some complications and disagreements among themselves as to certain points, which they wish to clear up, and state, therefore, that the complete report will be made at the January meeting, 1914. The Committee appointed last year to coöperate with the Committee appointed by the National District Heating Association has been appointed again, but the chairman of the last year's committee, which met at Indianapolis two months ago, may have a word to say in reference to what they did and what they propose to do. It is not expected that a complete report will be made, but simply a remark or two in reference to what they are driving at, in addition to the remarks made by the President of that Association, Mr. Bushnell. Mr. Capron, have you anything to say?

Mr. Capron: I do not think I have anything to report at this time, except that the new committee has met to-day, and we will try to have some report at the January meeting.

President Hale: As you may know, some of you, there has been established in the City of New York a commission to investigate and make tests on standards for ventilation. That is being financed, you might say, by a fund provided by one of the Foundations, and, as Mr. Kimball of New York, who was here a moment ago, is a member of that commission, he has offered to say a few words explaining what they are aiming at and what they expect to accomplish. Unfortunately, Mr. Kimball has stepped out. I will call his attention to it when he comes back.

We have with us this afternoon the Secretary of the Industrial Bureau of the State Labor Department, Mr. John R. Shillady, who wishes to speak a few words, and we will be pleased to give the gentleman an opportunity at this time.

Mr. J. R. Shillady: I am a Buffalo man, and, happening to see your card hanging out here, "American Society of Heating and Ventilating Engineers," I thought it might not be out of place for me, as the Secretary of the new Industrial Board, to say a few words to the men here, especially to those who will be in the State of New York, as to just what this Board would like to do as it concerns you. The Department of Labor, provided the Governor and Senate can agree as to who will be the Labor Commissioner, will have more money and better equipment than any similar body in the United States. Among the things legislated upon last spring was the creation of an Industrial Board which began its work on the first of June this year. This Board consists of five, the Labor Commissioner as chairman, and four members appointed by the Governor. The Industrial Board has power to investigate the administration and effect of the Labor Law, as well as the power and responsibility of fixing standards of safety, sanitation, ventilation, lighting and fire prevention. Under very broad general powers it can do almost anything which ought to be done, provided it does not fall afoul of the courts by assuming powers which belong only to the legislature. The rules and regulations of the Board will have the force and effect of law, and take the same place on the statute books as

any other law. Its meetings are all public, and its proceedings are a matter of record. As to anything upon which the Board wishes to rule, it must give 10 days' notice by advertisement in such newspapers of the state as it may select. There are some paragraphs in the laws of New York State relating to ventilation. They define ventilation in a general way, and also provide that where dust, gases, fumes, etc., cause detriment, exhaust systems shall be provided. I think I will just read that part. The Board is not a technical board. The Secretary of the Board is a social worker. We have not yet outlined our program, as to the means to be taken by the Board to accomplish its ends, although a committee on program has reported to the Board, and that report is under consideration. There will be, in the Department of Labor, a division of Industrial Hygiene, when the Commissioner is appointed, which will consist of a mechanical engineer, a civil engineer, a chemical engineer, at least four medical inspectors, and 10 special investigators. This division will do the technical work required by the Board. The Board may make regulations peculiar to an industry or to a single machine or part of a factory. In other words, this is an attempt, instead of making 747 regulations or laws to cover every specific thing that might occur, to let the Industrial Board have the power to make regulations to cover specific situations. The idea which most of us upon the Board have, and that is the reason I am talking to you this morning is, that we shall endeavor to have the people who know the most about the job work it out. It is our hope that, by putting this thing up to such men are you are—we may ask you to serve on some of our committees, without compensation, as the Board has no power to compensate—we may, perhaps, get your coöperation for the good of the workers of this state. We can say to the people immediately affected: "This Board has certain powers and certain responsibilities. If you want to come in with us and help us work this thing out, we will be glad to have you." We may say, also, "if we have to, and you do not care to coöperate with us, we will go ahead and do it anyway." We hope to work with the people who understand the problems, and to enlist in the service of the state the intelligence of the community. One of the misfortunes of legislating is that there are not many men who know what there is to

know about everything. We hope to be able to call such men as you before the Board, and to be able at least to have your advice. Mr. Chairman, I thank you for this opportunity.

President Hale: We are very glad to hear the remarks by the speaker, and he may be sure that any of our members will be glad to coöperate at any time he may wish to call upon us. Let the Secretary know, and we will see if we can get together sometime. There are several resolutions to be offered. Prior to that, however, it may be mentioned here that at our summer meeting in Detroit last year there were registered 116 total, of which 48 were actually members. The others were guests. At this meeting we have 133 registered, of which 75 are members. (Applause.) It shows that we made no mistake in selecting Buffalo as a meeting place. In reference to the membership, the Council had a meeting yesterday and discussed at length as to the possibility of getting in new members, and at their suggestion the Chair is going to put it up to the members here to-day, the question as to whether they will obligate themselves to bring in another member by January. It is an easy thing; we can all do it if we try, and that is going to bring in greater revenue, and make it possible for us to accomplish more than we have in the past. Will the members here obligate themselves to bring in one member before the next annual meeting? All who will, kindly stand up. (Counting.) Twelve, thirteen, and I will obligate myself, fourteen.

Mr. Weinshank: Being a member of the Membership Committee, I will offer my services to this extent. I will write a letter to every member, sending him an application blank, and asking him to give me the names of persons who are eligible to become members. If he cannot reach those himself, I will write to those people, send them a copy of our Constitution and By-laws, and ask him, if he sees fit, to join this Society. Mr. Chew stated from this floor that the Society consists of 500 members, and there were only 20 per cent. of them doing the real hard work. The rest of them are lookers-on, and hangers-on. As a matter of fact, we must have more members to accomplish more. As Dr. Hill demonstrated to-day, we have just started. It is our duty to do real work. The country is looking to us for results. We have got to have some work done; we must have more members, so that the same ratio of

workers will increase. If you get a letter from me within the next thirty days you will know the purpose. Do not throw it into the waste basket. Give it to some one.

Dr. Hill: I did not arise; I didn't know whether it applied to associate members or not.

President Hale: It certainly does. There are several resolutions which I understand are to be offered.

Professor Hoffman: In every meeting of this Society there is considerable arduous and necessary work to be done by the Local Committee. This meeting has been no exception, and the members and lady friends have been well taken care of. In appreciation, therefore, of the work of this committee, I move you that the Secretary extend a vote of thanks to the Local Committee, and especially mention the splendid work of the chairman of that committee, Mr. Busey, for the work they have done for us at this meeting. (Motion seconded and carried.)

Mr. Addams: I would like to offer a resolution, expressing our appreciation to the American Radiator Company, and especially those of their organization who are with us, for the entertaining hospitality that we received yesterday, and the courtesy of the demonstration at their research laboratory, where it seems nothing was withheld, and everything shown to interest and please us. (Motion seconded and carried.)

A Member: I would like to move you at this time that the Secretary cast a vote of thanks and appreciation of this Society to the Buffalo Forge Company for their kindness and courtesy in opening their plant for our inspection yesterday afternoon, and in providing personal guides to take us all through their plant. (Motion seconded and carried.)

Mr. Donnelly: Mr. President, I believe that there are still some more of the Entertainment Committee features left in going to Niagara Falls this afternoon. North Tonawanda is right on the way there, and, if any of us are interested in the American District Steam Company plant, they have very kindly given us an invitation to visit there this afternoon. I visited their old plant at Lockport some years ago, and I think now, or at any time the Steam Company and Mr. Bishop will be glad to see us, and I would like to make a motion for a vote of thanks to Mr. Bishop and the American District Steam Company. (Motion seconded and carried.)

President Hale: The Secretary announces that the plant will be open this afternoon. All those who wish to visit the plant will be welcome. A while ago we stated that we would be glad to hear from the member of the New York Commission appointed to investigate Ventilation Standards, etc. I am glad to say that Mr. Kimball has come into the room and we will ask him to say a few words.

Mr. Kimball: I think you have read in the press of our Ventilation Commission. The fund is given through the New York Association for Improving the Condition of the Poor, and the appointment of the members of the Commission, as suggested by them, has been made by the Governor of the State. The Commissioners consist of Prof. C. E. A. Winslow, of the College of the City of New York, a public sanitarian expert of the City of New York; Dr. Miller, of Bellevue Hospital, and a practicing physician, as medical member; Professor Lee, of the College of Physicians and Surgeons, as physicist; Prof. Phelps, of Massachusetts Institute of Technology, as laboratory expert; Prof. Thorndike, of Teachers College, psychologist, and your humble servant, as engineer. The plan proposed is to subdivide the work, in a sense, placing each department in the charge of these different men, and meeting monthly or oftener to correlate the work and give it general direction. We have already employed a secretary for general work, who is a technical man, and who will also be used in laboratory work. We have employed Mr. Palmer, who is a post-graduate of Massachusetts Institute of Technology, and who has been with the Board of Health of New Jersey, and additional men will be employed from time to time until we will probably have a staff of five or six men handling different departments of the work. The fund available is $50,000, and the work is expected to cover a period of from four to ten years. The Commission has arranged for two rooms at the College of the City of New York for a general experimental plant. In one room we are placing an experimental plant for ventilation work. That takes the air from the roof, a small fan forces it through a Vento heater and through a small air washer, specially built, but of standard arrangement. Under the air washer is a drying chamber, which is merely a sheet-iron chamber, through which the air will be passed over calcium chloride, so that we can mix the wet and dry air and get any

relative humidity that we wish, to almost absolutely dry air. Then the air goes through reheaters and from there through ducts into the two rooms. We have called one room the operating room and the other the observation room. We have both steam jets and water jets, so that we can provide humidity by other means than the washer, if we want to, and provide for complete saturation. There is an elaborate system of temperature and humidity control. There is also provided an exhaust fan discharging out of the opposite side of the building. We can experiment on both outside air and recirculated air. We have every device that we can think of for measuring and testing the air.

In the observation room there will be placed subjects upon which tests of the effect of different atmospheric conditions will be made. They may be put in there from one hour to four weeks. They will be given arithmetical work, typewriting and reading. Their physical fatigue will be tested by means of the ergometer and their blood pressure, body temperature and pulse will be recorded.

This will give you a general idea of the work at the College of the City of New York. Then beyond this the Commission hopes to work in the industrial field. We have a man whom we are associating with the Commission who will make records in factory work, and we hope also to tie up with some office investigation and some school work and some hospital work. One of the first things that we propose to do is to establish a library on everything that we can find on the subject of ventilation and make that complete, covering all the recent publications on that subject. Then we hope also to associate with us, or at least to get some connection with all the different investigators on the subject, and in some way to make this a central or record bureau for all of these tests. We have not great hopes of making a pronouncement within two years, and, if we are able to make a final and satisfactory one in four years we shall be well satisfied.

President Hale: The Secretary has some announcements to make.

Secretary Scott: If the members who are considering preparing papers for the next annual meeting will have them in the hands of the Secretary by December 1 he will promise to mail

them to the members not later than January 1. It has been a rather trying experience to get these papers out in time for the semi-annual meeting in advance. I simply had to threaten and use all my persuasive powers with the printers. It seems to me that it will make our meeting much more valuable if we can mail the papers to the members at least three weeks in advance of the meetings. That will give the author and others who are familiar with the subject opportunity to prepare discussion on the papers as they are presented. The discussion is certainly a valuable part of our meeting, and I think can be made more valuable if the papers could be distributed in advance. This is the first invitation to the membership to contribute papers for the next annual meeting. I have one paper in hand now for it.

Mr. Kimball: I just wanted to say, regarding the Ventilating Commission, that I wish the members of the Society to feel interested, for we want their coöperation. I am not responsible for my appointment, and may not assemble any representation of the Society, but I would be glad to feel that I could represent the interests of the Society in this work and count upon the support and coöperation of the Society.

A Member: I move we adjourn.

The motion was seconded and carried. Meeting adjourned.

LIST OF MEMBERS AND GUESTS AT THE SEMI-ANNUAL MEETING OF THE A. S. OF H. & V. E., BUFFALO, N. Y., JULY 17, 18, and 19, 1913.

MEMBERS

A. S. Armagnac.
Homer Addams.
John R. Allen.
F. L. Busey.
R. P. Bolton.
W. L. Bronaugh.
J. H. Bacon.
E. P. Bradley.
C. R. Bishop.
D. S. Boyden.
S. M. Bushnell.
J. A. Bendure.
A. G. Cripps.
Chas. F. Chase.
M. S. Cooley.
Ralph Collamore.
W. H. Carrier.
E. F. Capron.
J. A. Donnelly.
J. H. Davis.
Richard Dawson.
A. C. Edgar.
M. L. Foote.
John F. Hale.
J. D. Hoffman.
H. M. Hart.
Norman A. Hill.
E. Vernon Hill.
Wm. M. Kingsbury.
Walter J. Kline.
D. D. Kimball.
Roy E. Lynd.
F. J. Lennox.
E. C. Lillie.
S. R. Lewis.
J. I. Lyle.
E. A. May.
W. E. Marquam.
E. K. Munroe.
R. B. MacKinnon.
F. G. McCann.
W. F. McDonald.
H. B. McLelland.
Chas. F. Newport.
H. M. Nobis.
L. H. Prentice.
Frank Phegley.
J. M. Stannard.

L. C. Soule.
John T. Sadler.
F. R. Still.
E. A. Scott.
B. K. Strader.
Ralph C. Taggart.
W. F. Verner.
T. Wilson.
Theo. Weinshank.
A. E. Werkhoff.

GUESTS.

H. V. Ackert.
Harry Allallay.
Paul Kelvin Addams.
W. H. Butler.
John Boylston.
Jos. F. Brightman.
W. M. Braemer.
J. R. Drozeski.
C. J. Doughty.
G. H. Drake.
E. C. Evans.
W. M. Foster.
J. H. Foresman.
C. B. Foster.
F. G. Gregory.
Wm. Hutton.
H. M. Hill.
J. B. Howell.
R. C. Holley.
R. W. Hutton.
H. D. Joyce.
K. C. Kimball.
John Montgomery.
H. Maltby.
J. F. McIntire.
H. P. Mishler.
Jos. Meehan.
F. E. McCann.
W. R. Marquam.
L. F. Marquam.
J. H. Maddin.
Harold Newman.
S. Pearson.
R. Rouse, Jr.
C. T. Graham-Rogers, M. D.
W. S. Ramson.
Albert W. H. Spear.
F. W. Smeit.
E. Scholfield.
J. B. Snellgrove.
J. R. Shillady.
R. A. Sehl.
L. A. Weager.
J. C. Wright.
Ralph Winn.
E. K. Webster.
S. Wright.

LADIES.

Mrs. Homer Addams.
Mrs. F. L. Busey.
Mrs. R. P. Bolton.
Mrs. W. L. Bronaugh.
Mrs. S. M. Bushnell.
Mrs. Ralph Collamore.
Mrs. M. S. Cooley.
Mrs. W. H. Carrier.
Miss Capron.
Mrs. J. H. Davis.
Mrs. John F. Hale.
Mrs. N. A. Hill.
Mrs. M. Kingsbury.
Mrs. W. E. Marquam.
Mrs. F. G. McCann.
Miss J. McLelland.
Mrs. F. G. Phegley.
Miss Phegley.
Mrs. G. M. Rehm.
Mrs. Theo. Weinshank.
Miss Anna Weinshank.

CCCXXI.

ADDRESS BY PRESIDENT JOHN F. HALE, AT THE SEMI-ANNUAL MEETING, AT BUFFALO, N. Y., JULY 17, 1913.

Gentlemen: The nineteenth semi-annual meeting of the American Society of Heating and Ventilating Engineers is now in session, and, as President, I greet you, extending at the same time a hearty welcome to our visitors and guests.

The by-laws of our Society do not make it obligatory for us to hold a summer session, but leaves the decision to the discretion of the officers. After careful consideration, this beautiful and hospitable city of Buffalo was selected as our meeting place this year, not only because of its geographical location, but on account of the very urgent invitation extended by those manufacturers whose plants and laboratories are situated here, and from whom we shall receive assistance in solving some of the problems we have under consideration.

The program prepared for this meeting is made up largely of papers written by men of the Central West, and the diversified nature of the subjects will no doubt make this meeting of more than passing interest to all.

The unique feature of this meeting will be the visit to the "Institute of Thermal Research," where our hosts will place at our disposal both steam and hot-water heating boilers, blast coils, and a heating system, all set up for testing purposes, so that we may observe their operation and be better able to follow the papers to be read.

This is especially true in the case of the paper by L. C. Soule, of Chicago, who will show us the actual apparatus in operation from which he gathered the data upon which his paper was based.

This year we are operating the affairs of the Society under the revised constitution and by-laws, and your governing officers, now known as the Council, consist of twelve members instead of ten as in the past.

This gives us a greater number among whom to divide the work, and makes it possible for the first time to have an executive committee whose duties are the supervision of the Secretary's office, and it gives me great pleasure to state that this committee has done excellent work during the first half of the year.

The absence from the country of Mr. W. W. Macon and Mr. Frank T. Chapman, both members of this committee, came after the work had been done, and, although they are not with us to-day, the Chair wishes to express his appreciation at the very able assistance given.

At the beginning of the administration, the Society membership consisted of 449 members, to which has been added 27 by the election of June 27, 1913. We have lost 3 by resignation, 2 by death, and 4 for failure to qualify, making the total membership on July 17, 1913, 467. There are now 10 applications in the hands of the Membership Committee, and as many more have expressed their intention of applying.

It is more than likely that when the report is made at the annual meeting in January the membership will have been deducted below the 450 mark, as there will probably be a weeding out of delinquents, so that those on the books are only those who think enough of the Society's welfare to pay their dues.

There will always be found those who are anxious to be identified with a body such as ours, but who neither pay their dues nor assist in committee work nor with papers, and such we do not care for. It may be possible that a few of the delinquents are forgetful or careless in the matter, but if they wish to prevent the possibility of having their names read as having been dropped for cause, they had better look up their check book and send in the balance due.

One would think that from a membership such as ours, it would be possible to find enough men who would give sufficient of their time to give some assistance in committee work, but it has been the Chair's experience that the workers are few and far between. The delay in appointing committees this year was occasioned by an attempt to select only members that would get together with their associates and hand in a report worth while, but even now it is feared that the excuses are many and the personnel of the various committees has had to be changed.

This condition of affairs has worked a hardship on some of the willing ones, and they probably have been taken advantage of, for you may find the same name on several committees.

When you signed an application for membership in the Society you agreed "to promote the objects of the Society as far as was in your power," and subscribed to the several articles in the Constitution and By-laws, but it is a regrettable fact that the workers can be named almost from memory.

The Chair wishes to appeal to all present, and through them and this message to all of our members throughout the country, for a greater coöperation and interest in the Society's affairs.

We have the better part of the year before us, and it is yet seven months before the annual meeting, and we are looking forward with great expectation, but in order to get results it will be necessary for all to pay their dues, for committees to burn some midnight oil in the preparation of their reports, and for those who have something to tell, and a willingness to tell, to get busy and put it into the form of a paper and in the hands of the Secretary before December 15, 1913.

Your Council is very much in earnest in its endeavors to advance the Society in the engineering world, but they must have your help, so let us all put our shoulder to the wheel, and push—for in union there is strength.

It is gratifying to note that many of those in attendance have brought their wives and daughters, and to them a most cordial welcome is extended. The Committee on Entertainment has prepared automobile rides and day trips for the ladies while we are having our meetings, and we have purposely omitted all evening sessions, so as not to interfere with your pleasure, but the Chair wishes to express the hope that the members will be present at all of the meetings as far as possible, working while there is work to do, leaving the play for the hours set aside for that purpose.

It was thought that the ladies would not be interested in the tests at the Institute of Thermal Research, so the committee have planned to take them to East Aurora, where Fra Elbertus holds forth, and it is hoped that while they are being entertained in that way we may spend our time most profitably in the search for knowledge.

JOHN F. HALE,
President.

CCCXXII.

TIME ANALYSIS IN STARTING HEATING APPARATUS.

BY RALPH C. TAGGART.

In figuring the time that is required to warm up or start heating apparatus we must first make a proper allowance for the starting of the fire, or bringing it, if banked, to its normal operating condition. If the water in the boiler is cold, we should also allow for the warming of the water and iron in the boiler itself. As boilers are generally covered with a heat insulating covering, the loss in heat from the outer surface of the boiler is usually small and does not, as a rule, need to be considered separately. If, however, the boiler is not covered with an insulating covering, we may ordinarily charge the loss in heat directly against the heat producing capacity of the boiler.

The question of the heat producing capacity of the boiler is one which may be figured or which may often more satisfactorily be obtained from the "Boiler Performance Curves" of the manufacturer. These boiler performance curves show the steam producing capacity of the boiler under different conditions of operation and they are now being furnished by enterprising boiler manufacturers. It is very desirable that the engineer should have such boiler performance curves at his disposal.

From the boiler performance curves one can determine the steam or B. t. u. which the boiler can properly produce in a given time, say one hour or one minute. The weight of the iron and water in the boiler can also be obtained from the manufacturer or by measurement.

In the case of a cast-iron boiler the weight of the iron in pounds should be multiplied by 0.13, the specific heat of cast-iron. The product will be the weight of water to which iron is equivalent in heat absorbing capacity. This amount should be

added to the weight of water in the boiler and this sum multiplied by the difference in temperature, Fahrenheit, through which the iron and water in the boiler is to be raised. The product will, of course, represent the B. t. u. which must be given to the iron and water before steam is produced. If, therefore, we can determine the average heat producing capacity of the boiler in B. t. u. per unit of time, we can divide the total B. t. u. required to heat the iron and water in the boiler by the B. t. u. which the boiler will produce in a unit of time and find the number of units of time, whether they are minutes or hours.

After we have figured the time required to heat the boiler we can figure the time required to heat the piping and radiation in the heating apparatus itself. This latter is quite a different question from the former and in considering it we will first confine our attention to steam heating apparatus.

In the heating of the piping and radiation, a large part of the heat supplied by the boiler may, after part of the apparatus is warmed up, be used in giving off heat to surrounding objects, and this part is not, therefore, available for use in heating the remainder of the apparatus.

In the solution of this problem we will use the following symbols:

H equals heat, measured in lb. of steam* (or B. t. u.) which at any instant has been used to heat the pipes and radiators in the heating apparatus. This is a quantity which is zero when we start to heat the apparatus and which varies every instant until the apparatus is heated, at which time it equals I as listed below.

t equals time (let us say in minutes).

B equals pounds of steam (or B. t. u.) per minute supplied by the boiler. B is considered constant.

I equals the total heat, measured in pounds of steam (or B. t. u.) which is required to heat the iron in the pipes and radiation.

R_1 equals pounds of steam per minute which the whole apparatus will condense (or the B. t. u. which will be given off) with the piping and radiation at approximately the temperature

*We must, of course, use consistently as our unit either the B. t. u. or the heat obtained from 1 lb. of steam.

of the steam while the temperature of the room is equal to that which it has when steam is first turned into the apparatus.

R_2 equals the same as R_1 except that the temperature of the room is equal to that which it has when the apparatus becomes completely heated.

We have spoken of using as the measure of the heat the heat contained in 1 lb. of steam. This means, of course, the heat which 1 lb. of steam will give up by condensation within the radiation. We may, however, change the unit to B. t. u. in each case, if we wish, and it will make no difference in our formulæ.

We will let $\frac{dH}{dt}$ represent the rate at which the increase in heat in the iron of the piping and radiation varies with the time, or $\frac{dH}{dt}$ equals the rate at which the iron in the piping and radiation heats up.

At the start all the heat given up by the steam, which is supplied by the boiler, is used in heating the iron in the pipes and radiators, so that at the start

$\frac{dH}{dt}$ equals B, which is the total heat supplied by the boiler.

At any instant later, however, the rate of the heating of the iron in the piping and radiation is less because a part of the heat supplied by the boiler is given off to surrounding objects by the piping and radiation which is already heated. This amount varies at every instant as an increasing amount of the piping and radiation is heated.

R_1 equals the rate at which the piping and radiation give off heat with a difference in temperature between the heated pipes and the surrounding room such as we have at the start. If we assume for a moment that this is the rate at which the apparatus always gives off heat, a part of it would give off a portion of R_1 corresponding to the part of the piping and radiation which is heated. But if H represents the part heated at any instant and I represents the total amount to be heated, then $\frac{H}{I}$ represents the fraction of the total which is heated at any in-

stant and therefore R_1 times $\frac{H}{I}$ represents the heat which is given off per unit of time by the radiation already heated, and this portion of the heat supplied by the boiler cannot be used to heat additional parts of the apparatus.

The rate, therefore, at any instant at which the radiation and piping are heated, $\frac{dH}{dt}$ equals $B - R_1\frac{H}{I}$. (1)

This, however, is only true if R_1 equals R_2, that is, if the piping and radiation give off a constant amount of heat per square foot during the warming up process. As, however, the room becomes gradually warmer the rate of giving off heat changes and R_1 at the start becomes R_2 when the apparatus is warmed. We may say, however, that in changing from R_1 to R_2 the heat given off per square foot of surface varies as the difference* in temperature between the heated radiation (including the piping) and the room itself. In such a case the rate at which heat is given off is less than R_1 by a certain amount which varies continuously, depending upon the fraction of the apparatus that is heated.

When the apparatus is entirely heated the amount by which R_1 should be decreased is equal to the difference between R_1 and R_2 or $(R_1 - R_2)$, and when the apparatus is partly heated the fraction heated is represented by $\frac{H}{I}$. We see, therefore, that R_1 should be decreased by $\frac{H}{I}$ times the difference between R_1 and R_2 or R_1 should be decreased by $(R_1 - R_2)$ times $\frac{H}{I}$.

If, then, in equation (1) we decrease R_1 by this amount we get

$$\frac{dH}{dt} = B - \frac{H}{I}\left[R_1 - (R_1 - R_2)\frac{H}{I}\right] \text{ or}$$

$$\frac{dH}{dt} = B - \frac{H}{I}R_1 + \frac{H^2}{I^2}(R_1 - R_2) \qquad (2)$$

Now (2) is an equation showing the rate at which the heat in

*This may be considered absolutely true when the difference between the temperature of the hot pipes and the room lies between 220 deg. F. and 120 deg. F.

the piping and radiation varies in terms of B, I, R_1, R_2, and H, where the time t and the heat in the iron H are the only two varying quantities. From equation (2) we can deduce the relation between these various quantities as follows:

$$\frac{dH}{dt}=B-\frac{H}{I}R_1+\frac{H^2}{I^2}(R_1-R_2)$$

$$\frac{dH}{dt}=\frac{BI^2-HIR_1+H^2(R_1-R_2)}{I^2}$$

$$dt=\frac{I^2dH}{BI^2-HIR_1+H^2(R_1-R_2)}$$

$$\int dt=\frac{I^2}{R_1-R_2}\int\frac{dH}{\frac{BI^2}{R_1-R_2}-\frac{IR_1}{R_1-R_2}H+H^2}$$

Let $P=\dfrac{I^2}{R_1-R_2}$

Let $Q=\dfrac{IR_1}{2(R_1-R_2)}$

Then $\int dt=P\displaystyle\int\frac{dH}{\frac{BI^2}{R_1-R_2}-2QH+H^2}$

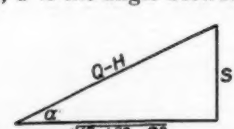
$$\int dt=P\int\frac{dH}{(Q-H)^2-\left(Q^2-\frac{BI^2}{R_1-R_2}\right)}$$

Let $S=\sqrt{Q^2-\dfrac{BI^2}{R_1-R_2}}=\sqrt{\dfrac{I^2R_1^2}{4(R_1-R_2)^2}-\dfrac{BI^2}{R_1-R_2}}=$

$$\frac{I}{2(R_1-R_2)}\sqrt{R_1^2-4B(R_1-R_2)}$$

Then $\int dt=P\displaystyle\int\frac{dH}{(Q-H)^2-S^2}$

Now Q — H can be considered the hypothenuse of a right angle triangle when S and $\sqrt{(Q-H)^2-S^2}$ will represent the other two sides. If, therefore, α is the angle between the sides Q — H and $\sqrt{(Q-H)^2-S^2}$



Then

$$\frac{1}{\sin\alpha}=\frac{Q-H}{S}$$

and by differentiation

$$-\frac{\cos\alpha}{\sin^2\alpha}d\alpha=-\frac{1}{S}dH$$

$$dH = S\frac{\cos\alpha}{\sin^2\alpha}d\alpha$$

Now

$$\frac{\sqrt{(Q-H)^2-S^2}}{S} = \frac{\cos\alpha}{\sin\alpha}$$

$$(Q-H)^2-S^2 = S^2\frac{\cos^2\alpha}{\sin^2\alpha}$$

Whence by substitution in the last equation giving the value of $\int dt$ we have

$$\int dt = P\int\frac{S\frac{\cos\alpha}{\sin^2\alpha}d\alpha}{S^2\frac{\cos^2\alpha}{\sin^2\alpha}} = \frac{P}{S}\int\frac{d\alpha}{\cos\alpha} = \frac{P}{S}\int\sec\alpha\cdot d\alpha$$

Whence

$$t = \frac{P}{S}\log(\sec\alpha + \tan\alpha) + \text{constant}$$

Substituting the values of the secant and tangent

$$t = \frac{P}{S}\log\left(\frac{Q-H}{\sqrt{(Q-H)^2-S^2}} + \frac{S}{\sqrt{(Q-H)^2-S^2}}\right) + \text{Constant}$$

$$t = \frac{P}{S}\log\left(\frac{Q-H+S}{\sqrt{(Q-H)^2-S^2}}\right) + \text{Constant}$$

$$t = \frac{P}{S}\log\sqrt{\frac{Q-H+S}{Q-H-S}} + \text{Constant}$$

$$t = \frac{P}{2S}\log\frac{Q-H+S}{Q-H-S} + \text{Constant.}$$

Since $t = 0$ when $H = 0$.

$$0 = \frac{P}{2S}\log\frac{Q+S}{Q-S} + \text{Constant.}$$

$$\text{Constant} = -\frac{P}{2S}\log\frac{Q+S}{Q-S}$$

$$t = \frac{P}{2S}\log\frac{Q-H+S}{Q-H-S} - \frac{P}{2S}\log\frac{Q+S}{Q-S}$$

$$t = \frac{P}{2S}\log\frac{(Q-H+S)(Q-S)}{(Q-H-S)(Q+S)}$$

$$t = \frac{P}{2S}\log\frac{Q^2-S^2-HQ+HS}{Q^2-S^2-HQ-HS}$$

Substituting the values of P, Q and S but letting

$$\sqrt{V} = \sqrt{R_1^2-4B(R_1-R_2)}.$$

We have $t = \dfrac{\dfrac{I^2}{R_1-R_2}}{\dfrac{I}{R_1-R_2}\sqrt{V}}$ multiplied by

$$\log \frac{\dfrac{I^2R_1^2}{4(R_1-R_2)^2}-\dfrac{I^2}{4(R_1-R_2)^2}V-\dfrac{HIR_1}{2(R_1-R_2)}+\dfrac{HI}{2(R_1-R_2)}\sqrt{V}}{\dfrac{I^2R_1^2}{4(R_1-R_2)^2}-\dfrac{I^2}{4(R_1-R_2)^2}V-\dfrac{HIR_1}{2(R_1-R_2)}-\dfrac{HI}{2(R_1-R_2)}\sqrt{V}}$$

Simplifying and substituting the value of V.

$t = \dfrac{I}{\sqrt{R_1^2-4B(R_1-R_2)}}$ multiplied by

$$\log \frac{IR_1^2-I[R_1^2-4B(R_1-R_2)]-2HR_1(R_1-R_2)+2H(R_1-R_2)\sqrt{R_1^2-4B(R_1-R_2)}}{IR_1^2-I[R_1^2-4B(R_1-R^2)]-2HR_1(R_1-R_2)-2H(R_1-R_2)\sqrt{R_1^2-4B(R_1-R_2)}}$$

$t = \dfrac{I}{\sqrt{R_1^2-4B(R_1-R_2)}}$ multiplied by

$$\log \frac{2BI-HR_1+H\sqrt{R_1^2-4B(R_1-R_2)}}{2BI-HR_1-H\sqrt{R_1^2-4B(R_1-R_2)}}$$

We find, therefore, that

$t = \dfrac{I}{\sqrt{R_1^2-4B(R_1-R_2)}}$ multiplied by

$$\log \frac{2BI-R_1H+H\sqrt{R_1^2-4B(R_1-R_2)}}{2BI-R_1H-H\sqrt{R_1^2-4B(R_1-R_2)}} \qquad (3)$$

This equation, which we will call (3), is the fundamental equation.

The logarithms which must be taken are the hyperbolic or natural logarithms and if we wish to use the common logarithms (base 10) we must divide the common logarithms by 2.3.

We may find in using equation (3) that in a few special cases the quantity under the radical is negative. This does not ordinarily happen, however. In any such special case the formulæ, etc., can be worked out in a manner similar to what is shown in the paper, with $(Q-H)^2+S^2$, instead of $(Q-H)^2-S^2$.

If the temperature of the rooms in which the pipes and radiation are located does not change, R_1 becomes equal to R_2 and equation (3) reduces to

$$t = \frac{I}{R_1} \log \frac{BI}{BI-R_1H} \qquad (4)$$

If we wish to find the time at which the apparatus becomes entirely heated, it is when H equals I, in which case equation (3) becomes t (equals time of fully heating pipe and radiation) =

$$\frac{I}{\sqrt{R_1^2-4B(R_1-R_2)}} \log \frac{2B-R_1+\sqrt{R_1^2-4B(R_1-R_2)}}{2B-R_1-\sqrt{R_1^2-4B(R_1-R_2)}} \qquad (5)$$

We see from equation (5) that the time of fully heating the pipes and radiation is shown by an equation in which I does not appear in the logarithm and therefore I varies directly as t. This means that when there is a fixed proportion between B, R_1 and R_2 or the amount of steam furnished by the boiler and that required by the heating apparatus (both at the start and when the apparatus is warmed up) we can figure the time in terms of the quantity of iron in the piping and radiation. If the quantity of iron, however, in the piping and radiation is in some fixed proportion to the radiation itself (as it ordinarily is) we can fix the time entirely independently of the size of the apparatus.

In order to illustrate the use of equation (5) certain examples and curves are worked out and an equation similar to equation (5) will also be discussed in connection with hot water heating.

In Fig. 1 each curve represents a condition in which there are certain fixed temperatures in the building at the start and also when the apparatus is completely warmed up. For example, one curve is marked 50 deg.-70 deg. F. This means that the building is at a temperature of 50 deg. F. when steam starts to enter the apparatus and that the building is at a temperature of 70 deg. F. when the apparatus is completely warmed. It may be necessary to first guess at the second temperature of the building in order to determine a time for the warming of the apparatus and when we have fixed on an approximate time for the warming of the apparatus we can then determine from the known conditions of any particular installation, more exactly what the second temperature of the building will be, and so by reference once more to the curves or equation we can fix very closely the actual time of the warming up of the apparatus.

The curves are worked out for a radiator temperature of 220 deg. F. and on the basis that each square foot of radiation gives off 250 B. t. u. per hour.

It is important to notice, however, that so long as we have a correct relation between the steam furnished by the boiler and the rate at which it is given off by the radiation, the other factors affect only I in the formula and the time varies exactly as I does.

For example, the curves are worked out for a weight of 7 lb. of cast iron to each square foot of surface, as explained later in detail. Let us consider the case of piping where 300 B. t. u. are given off per square foot of surface and where there are 6 lb. of iron per square foot of surface, the specific heat of wrought iron being about 1/8 less than that of cast iron. The heat taken to heat the iron as compared with the other factors will be less

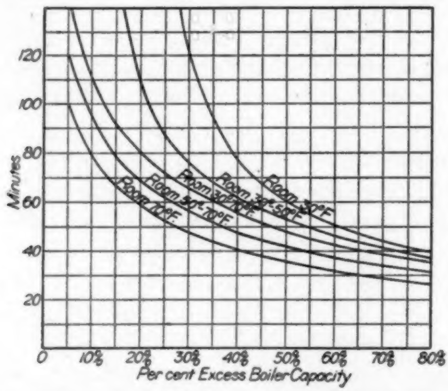


FIG. 1.—CURVES SHOWING TIME REQUIRED TO HEAT STEAM RADIATION.
For pipe surface use from 5/8 to 3/4 of time shown.

in the ratio of 250 to 300. It will be less in the ratio of 6 to 7 because of the less iron per square foot of surface and it will be less in the ratio of 7 to 8 because of the lower specific heat of the iron. We may, therefore, for pipe take values equal to $\left(\frac{250}{300}\times\frac{6}{7}\times\frac{7}{8}\right)$ or 5/8 of those given for cast-iron radiation.

The curves in Fig. 1 are plotted for different values for the per cent. excess of steam supplied by the boiler as compared with what the apparatus would require in normal operation or when the temperature of the building is about 70 deg. F. The other values plotted are the times in minutes for the complete heating of the apparatus.

Let us, for example, consider the case where the building is at

50 deg. F. when steam first enters the apparatus, and at 70 deg. F. when the apparatus is warmed up. In such a case

$$R_1 = \frac{220-50}{220-70} R_2 = \frac{17}{15} R_2$$

When the steam furnished by the boiler is 40 per cent., for example, in excess of the steam required when the building is at 70 deg. F.

$$B = \frac{140}{100} R_2 = \frac{7}{5} R_2$$

Now we should find I, preferably in terms of R_2, and we do so as follows:

I equals heat required to heat iron.

R_2 equals heat given off by radiation per minute with room at 70 deg. F. This we will take as equal to $\frac{250}{60}$ times square feet of radiation. But 1 sq. ft. of radiation averages about 7 lb. of cast-iron.

So R_2 equals $\frac{250}{60} \times \frac{1}{7} \times$ lb. of iron to be heated. But for each pound of iron there are required

0.13 times (220 — 50) B. t. u. to heat the iron, therefore, since the total B. t. u. to heat the iron equals I, there are

$$\frac{I}{0.13 \times 170} \text{ lb. of iron}$$

so that $R_2 = \dfrac{250\,I}{60 \times 7 \times (0.13) \times 170}$

$$\text{and } I = \frac{60 \times 7 \times (0.13) \times 170}{250} R_2 = 37.1 R_2$$

The reader will notice that this value $37.1\ R_2$ will be the same whether the heat is measured in B. t. u. or in any other unit, as the ratio between the units will appear both in the numerator and denominator, and hence cancel out.

The values of R_1, B and I can, therefore, be obtained as shown, and they were obtained in this way in order to figure the values for the curves in Fig. 1.

In Fig. 2 curves are shown which are similar to those in Fig. 1, except that they are figured for covered piping where the heat loss per square foot of piping is taken as 50 B. t. u. per hour.

If the piping is covered the time of the heating of the covered pipes can first be determined from the curves in Fig. 2 or from

equation 5, and we can usually figure that the total boiler supply, B, is first used in heating the covered pipes. When this is done the heat given off by the covered pipes can be subtracted from the boiler supply and the difference can be used as the steam supply, B, to the uncovered radiation and the time of heating the radiation itself can then be determined from the curves in Fig. 1, or from equation 5, and added to the time required for heating the covered piping.

In hot-water heating apparatus the heating of the iron and water in the boiler should be allowed for by including the water and iron in the boiler in the term I.

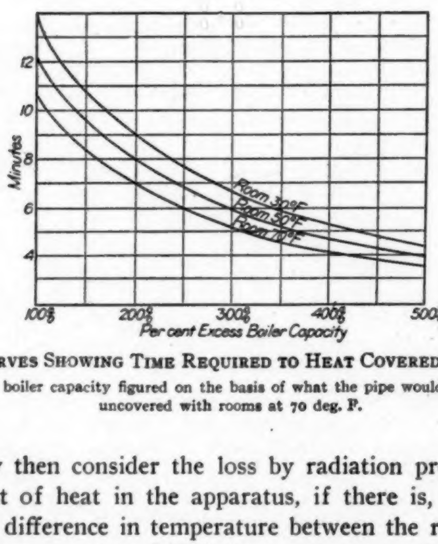


FIG. 2.—CURVES SHOWING TIME REQUIRED TO HEAT COVERED STEAM PIPING.
Excess boiler capacity figured on the basis of what the pipe would require if uncovered with rooms at 70 deg. F.

We may then consider the loss by radiation proportional to the amount of heat in the apparatus, if there is, at the start, some little difference in temperature between the room and the water in the apparatus. If this is not so, our calculation may be divided into several calculations, the periods being so chosen that during each of them the loss of heat will be approximately proportional to the heating of the apparatus. This means that it will usually be sufficient to divide the calculations into two, or at most three periods, because, although there will be some variation when the difference in temperature between the heating apparatus and the room is small, still, in this case, the heat loss itself is also relatively small, so that the error is proportionately decreased.

If, then, for hot-water apparatus the heat loss is R_1 times $\frac{H}{I}$ at the start and, if the R_1 increases to R_2 when the apparatus is heated, the heat loss at any instant is $\frac{H}{I}$ times R_1 plus the increased amount which must be added At the end of the heating process the extra amount to be added is the difference between R_2 and R_1, or $R_2 - R_1$, but at any intervening instant the extra amount is $\frac{H}{I}$ times $(R_2 - R_1)$. Therefore the heat given off by the radiation is

$$\frac{H}{I}\left[R_1+(R_2-R_1)\frac{H}{I}\right]$$

Therefore

$$\frac{dH}{dt}=B-\frac{H}{I}\left[R_1+(R_2-R_1)\frac{H}{I}\right]$$

$$\frac{dH}{dt}=B-\frac{H}{I}R_1-\frac{H^2}{I^2}(R_2-R_1)$$

which is similar to equation 2. Our resulting equation corresponding to equation 5 will, therefore, be

$$t=\frac{I}{\sqrt{4B(R_2-R_1)+R_1^2}}\log\frac{2B-R_1+\sqrt{4B(R_2-R_1)+R_1^2}}{2B-R_1-\sqrt{4B(R_2-R_1)+R_1^2}}$$

The curves in Fig. 3 are similar to those in Fig. 1.

It is interesting to notice that, if more radiation is installed and operated at a lower temperature, the same time is required to bring either quantity of hot-water radiation up to a temperature. This means that the time of heating the apparatus is approximately the same whether the apparatus is heated to 180 deg. F. or whether more radiation is installed so that it needs to be heated only to 140 deg. F.

If a part of the hot water piping is covered we may allow for it in the following manner: Suppose the part of the pipe that is covered would normally give off 25 per cent. of the total heat and that the heat given off from the covered pipe is one-fifth of what it would be without covering. The heat radiated is then $\frac{3}{4}+\frac{1}{5}\times\frac{1}{5}=\frac{75}{100}+\frac{4}{100}=\frac{79}{100}$ of what it would normally be. If, however, the boiler capacity is figured with respect to the heat required, taking the covered pipe into consideration, the

time would be $\frac{100}{79}$ of the time shown in the curves in Fig. 3, but as this is a case of pipe instead of cast-iron radiation 4/5 of this amount should be taken if all of the radiation is pipe, because of increased radiating effect, so that the time is $4/5 \times \frac{100}{79} = \frac{400}{395} =$ 101 per cent. of what is shown on the curves. This might also have to be increased if the pipes are large and so hold much more water per square foot of surface than does ordinary radiation. One and a half or two-inch pipe holds about the same amount of water per square foot of surface as does ordi-

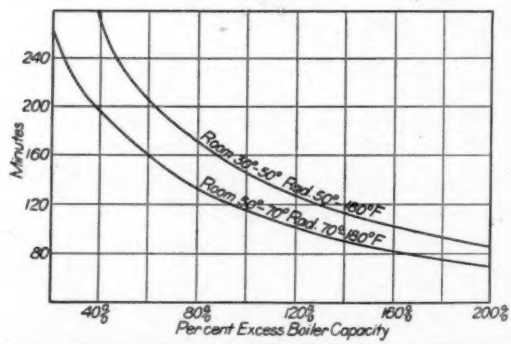


FIG. 3.—CURVES SHOWING TIME REQUIRED TO HEAT HOT-WATER RADIATION.

nary radiation. If we double the diameter of the pipe we double its surface, but we increase its contents four times, so that the water in the pipe per square foot of surface is doubled. The time, however, might only have to be increased, say, 50 per cent., because the iron in the piping and the iron and water in the boiler are not increased in this ratio per square foot of surface by the increase in the diameter of the pipe.

DISCUSSION.

Mr. Taggart: This question, "Time Analysis in Starting Heating Apparatus," is, it seems to me, of considerable importance. About a year ago there was a paper on a similar subject, which went into the discussion to some extent, and my paper

may, I think, be considered as a continuation of the analysis that Mr. Donnelly made at that time. The question as to the size of the boiler should often be determined, not by the question as to how much steam it will take to keep the apparatus running, but how quickly the apparatus must be heated up. Of course the question as to how quickly the building can be heated up must also be considered, but, if the heating apparatus is heated up at frequent intervals, and the fire is banked during the night, so that the building does not cool off to any great extent, then the question of the time taken to heat up the apparatus itself is the thing of prime importance, and, in any case, we must consider the question of the time required to bring the heating apparatus up to its full capacity. The size of the boiler is what largely determines this.

The results of my analysis are shown on the curves in the latter part of the paper. The first fundamental equation which shows the relations between various quantities involved, is equation number two, and the three or four following pages of mathematics might well, perhaps, have been put in small type to indicate that they are only matters of reference. It is not intended in reading this paper to force you to run through these equations. Of course, we want to be sure that they are right, but, in order to use them, the results only are necessary. The equations are put in here merely so that those who wish to check up the method by which the results are obtained can do so. The first equation, equation No. 2, although it looks a little complicated, is really quite simple. At the start, whatever steam the boiler makes must go into the iron. At any later time a part of the heat is radiated by the surface already heated up, so that this amount of heat cannot be used to heat up more iron. $\frac{H}{I}$ is the part of the total apparatus that is heated at any instant. H is the amount of heat in the iron at any instant, and I is the total amount of heat required to heat the iron. So we have to subtract from B $\frac{H_R}{I}$. Now that would be all there would be to this second equation, if it was not for one thing, and that is that the temperature of the room itself changes. Thus we have to subtract a factor representing the difference caused by the fact that the room does not remain at its original temperature.

Equation 5 is the equation which is used for the curves, but if you wish only approximate results, you can use equation 4, in which the temperature of the room is supposed to be constant, in which case, if we make H equal to I, the equation will become $t = \frac{1}{R} \log \frac{B}{B - R}$.

Figure 2 shows some curves referring to covered steam piping and you will notice in using these curves that we assume the covered steam pipe is heated first, and figure the boiler supply for the remaining apparatus as equal to the boiler supply minus the amount that the covered pipe would use.

In Figure 3 the results for hot-water radiation are given based on a total heat equivalent in the system of five pounds of water per square foot of radiation.

This covers the principal part of the paper. The results can be used from the curves without bothering about the equations, but if you want to use the equations you can, of course, use the final ones without going through the intermediate steps. The time taken to heat up an apparatus is the factor that should frequently determine the size of the boiler, although we often see in specifications a statement that the apparatus must maintain a temperature of 70 degrees when the temperature outdoors is zero, without any reference to the time taken up to heat the apparatus. Sometimes this is all right, but very often it is all wrong. In a building where steam is not kept up day and night the question may become very important.

President Hale: For the benefit of those who came in late I will repeat the remark to the effect that the questions which anyone may wish to ask will be noted by Mr. Taggart and answered at one time, rather than to permit of a general discussion back and forth on the floor, which takes unnecessary time, and gets us nowhere.

Mr. Cooley: I would like to ask Mr. Taggart if he assumed in making these calculations that the air was all out of the system automatically, or was any action necessary to exhaust the air? I understand Mr. Taggart to say that he took five pounds of water for each square foot of radiation, that he assumed that each square foot of radiation contained five pounds of water.

Mr. Verner: I take advantage of the opportunity of asking a question. In the paper it is stated the condition of the piping

and radiation, at the temperature of the steam. The statement is of no importance relative to the vital results, but I thought it might be changed somewhat to read in a different way. That is, the piping and radiation could not be at the temperature of the steam; if they were, you would not have any heat given off. You would have to have the temperature of the pipe and the radiation less than the steam to have the heat given off.

Mr. Taggart: In the ordinary heating apparatus, where the steam supply is not extravagantly large, the rapidity with which the air leaves the apparatus depends upon how fast the steam comes in. If you have an apparatus where the air is choked so that it cannot escape, the steam pressure runs up before the apparatus is entirely heated up, but that does not ordinarily happen. The steam pressure in the ordinary apparatus doesn't vary very greatly while the apparatus is warming up, and the chance for the air to escape is sufficient, so that the determining factor is not the number of air orifices, but the amount of steam that comes in. There may, of course, be cases where the chances for air to escape are so small that the pressure runs up in the apparatus while it is being heated up, but if this occurs to any great extent, the pressure gauge shows the trouble. It is assumed in these calculations that the chance for the air to escape is ample to let the air escape as fast as the steam is supplied. If the pressure does run up a little it does not make any material difference, because the rate at which the radiation gives off heat does not vary very much for relatively small differences in pressure.

In figuring five pounds of water per square foot of radiation I do not mean that one square foot of radiation holds five pounds of water. It doesn't. What I mean is this: For every square foot of radiation there is a heat-absorbing capacity approximately equal to five pounds of water. That is, if you take the amount of water in the radiators and add to that the amount of water in the boiler and piping, and add to that the heat equivalent of all the iron in the radiation, boiler and piping, and divide by the square feet of surface, you will get, approximately, five.

In regard to the question that Mr. Verner speaks of as to the temperature of the piping and radiation, there is, of course, a small difference between the temperature of the outside of the

radiation and the temperature of the steam, but it is so small when the pipe is surrounded by air in the ordinary direct radiation that we usually say that the temperature of the radiation is approximately the temperature of the steam.

In regard to R, I will say that R is not a variable but a constant. R is merely the rate at which the radiation would give off heat if the room stays at its original temperature. I assume at the start that the room stays at the same temperature while the apparatus is warming up. Later we assume that the temperature of the room changes, but I do not mean that R_1 changes. It does not change. From R_1 must be subtracted whatever change there is, and this is shown by the latter part of equation 2.

CCCXXIII.

EXPENSE OF OPERATING HEATING AND VENTILATING PLANTS.*

BY H. M. HART.

In order to simplify this subject of computing the operating cost of heating and ventilating in advance of construction, we have decided to take up four different classes of buildings, namely, residences, apartment buildings, schools, and office buildings. The information at hand was so conflicting and unsatisfactory for the residences and apartments that we will be very brief in our discussion of these buildings.

RESIDENCE HEATING.

Method of computing cost of operation: For this example we will take a room requiring 100 sq. ft. of direct steam radiation to maintain a temperature of 70 deg. when the outside temperature is 10 deg. below zero.

The maximum difference in temperature is — 10 deg. to 70 deg. = 80 deg. The average difference in temperature is 35 deg. to 70 deg. = 35 deg., which, theoretically, would mean that the radiator would be in use 35/80 or 43¾ per cent. of the time. Taking the heating season as seven months, or 5,040 hours, 43¾ per cent. of this time would be 2,205 hours, the theoretical number of hours that radiation would be in use. The average radiator gives off approximately 225 B.t.u. per square foot per hour. Therefore, the total B.t.u. per season would be estimated as follows:

$$225 \times 100 \times 2{,}205 = 49{,}612{,}500.$$

The average B.t.u. available per pound of anthracite coal is

*Based on report of committee comprising H. M. Hart, chairman, N. L. Patterson and G. L. Hubbard, to Illinois Chapter at regular monthly meeting, February 10, 1913.

estimated at 8,000; therefore, 49,612,500 ÷ 8,000 = 6,201 lb. of coal, or 3.1 tons per 100 sq. ft. of radiating surface.

The average indirect steam radiator gives off approximately 450 B.t.u. per square foot per hour. As it requires approximately 50 per cent. more radiation for indirect heating than direct heating, this would mean that it would take $\frac{450 \times 150}{8,000 \times 2,000} \times 2,205 = 9.3$ tons, to heat the same room within direct radiation.

In order to see how this checked up in actual practice, the actual fuel consumption in 10 residences was obtained from the owners, and the results are as follows:

TABLE OF FUEL CONSUMPTION IN TEN RESIDENCES.

	Bank Fires at Night	Automatic Control on Boilers	System	Sq. Ft. Direct Steam Equivalent	Sq. Ft. Indirect Steam Equivalent	Estimated Fuel Consumption in Tons	Actual Fuel Consumption in Tons
1	Yes	No	Steam	666	1,080	88	55
2	No	No	Water	1,350	1,800	148	60
3	Yes	Yes	Water	1,720	....	53½	40
4	No	No	Water	1,535	86	53	35
5	No	Yes	Water	1,340	730	86	45
6	Yes	No	Water	1,050	384	56	30
7	No	Yes	Water	1,215	312	57	40
8	Yes	Yes	Steam	1,296	384	64	45
9	No	Yes	Steam	878	2,100	157	70
10	No	Yes	Water	1,335	240	56	36

Of course there are various reasons for this discrepancy, but we have left these for open discussion.

APARTMENT BUILDINGS.

Methods of computing costs of operation are approximately the same as those for heating residences, except that semi-bituminous coal is usually burned at a saving of about \$3.50 per ton; the efficiency of such coal at \$4.50 per ton being about equal to that of anthracite coal at \$8.00. Thus the comparative cost of coal heating with semi-bituminous and anthracite coal for direct steam radiators is, theoretically, \$24 per 100 sq. ft. per season for anthracite coal and \$13.50 for semi-bituminous, such as Pocahontas. The objection to using soft coal is the increased attention required and the dirt.

The results found in actual practice were no more consistent than those found in dwellings, as will be seen by the accompanying table:

EQUIPMENT AND COST OF HEATING APARTMENT BUILDINGS.

Building No.	Boiler	Radiation, Sq. Ft.	Kind of Coal	Coal, Tons
1..............	2—42" x 10' 6" Firebox	3,435	Pocahontas	219
2..............	2—36" x 10' 0" Herbert	6,000	Pocahontas	334
3..............	1—30" x 8' 6" Firebox	900	Pocahontas	36
4..............	2—48" x 12' 0" Firebox	7,076	Pocahontas	465
5..............	2—48" x 12' 0" Firebox	3,900	Pocahontas	190
6..............	2—48" x 14'-0 H R T	7,340	Pocahontas	215
7..............	2—48" x 14'-0 H R T	5,259	Pocahontas	170

SCHOOL BUILDINGS.

The difficulty of securing any exact figures is apparent when we take into consideration the hours which these plants operate. Again, there are vacations cutting into the period of operation. If we assume 172 days of 8 hours each with an average temperature of 38 deg. and a temperature of heated air in the chambers at 120 deg. the figures agree fairly with actual coal burned. The figures given are for an entirely different class of buildings, yet it will be seen that the quantity of coal per cubic foot of air heated per season was close. What it would do in a large number of buildings we are not prepared to say.

Spalding School: Air per hour, 1,147,440 cu. ft.; blower, 72 × 42 in.; boiler, firebox, 720 sq. ft.; amount small egg average 106 tons, at $7 per ton, per season; 0.18 lb. coal per season per foot of air warmed.

Twenty-eight room buildings; 4,162,729 cu. ft. per hour; bituminous coal, 400 tons at $2.95 per ton; 0.19 lb. coal per season per foot of air warmed.

Rosehill School—Air per hour, 800,000 cu. ft.; horse-power motor, 5; amount small egg, 73 tons at $7 per ton; 0.18 lb. coal per season per foot of air warmed.

OFFICE BUILDINGS.

Mr. Hubbard was asked to give a brief outline of his general practice in estimating the cost of operation of the heating apparatus in office buildings, and Mr. Hubbard has very kindly responded with the following:

"I have been asked to state how I would estimate the cost of maintenance of a heating plant from plans. From this viewpoint the statements that I make must be more or less personal, for the premises on which I base calculations and the methods by which I arrive at the results may be widely different from those used by others. In fact, there will probably be a great difference in the results obtained by any two or more engineers, and yet the figures of cost of maintenance of plants that have come under my observation check sufficiently close to the results I have calculated that I feel justified in stating that the methods used furnish a very close approximation of what the cost will be.

"The smaller the plant the greater the cost of heating will be per square foot of radiation, largely on account of the cost of labor, but the question as to how much it will cost to keep his building heated properly is just as vital to the small owner as to the larger one, and that is one of the first questions asked of the architect.

"Assuming that the radiation shown on the plans is the correct amount for properly heating the building between the limits of outside and inside temperatures and that the ventilating equipment is also correctly proportioned, the first thing to determine is the amount of steam that will be used in producing the heat necessary to warm the building. For this it is necessary to estimate the percentage of the total radiation that will be in use continuously and the length of the heating season. For example, in the usual office building in Chicago, with direct radiation in all stories above grade and with ventilating equipment for all stories below grade. I would assume that 65 per cent. of the direct radiation would be in use for the full 24 hours per day for a period of 7 months and 50 per cent. of the fan coil surface for 10 hours per day for 6 months. With a condensation per square foot of direct radiation of ¼ lb. and per square foot of fan coil surface of 1½ lb., the total amount of steam required per year can readily be determined.

"Assuming that with the ordinary coal used and evaporation of 6 lb. of water per pound of coal can be obtained under all conditions of load and firing, day in and day out, the amount of coal required during the heating season can be obtained by dividing the steam used by 6. This reduced to tons and multiplied by the cost per ton (say about $2.60 under the usual conditions in Chicago) will give the cost of coal per year. Ash removals should be about 10 ct. per ton of coal, and the make-up water required should be about 5 per cent. of the total steam per year. The only other item to be considered is the labor, and this must be determined in each case on its own merits. There must, of course, be a man in charge, and as he will have to devote a large portion of his time to work in parts of the building outside of the boiler room, it is probably correct to charge one-third of his salary to the heating plant. In addition, there must be firemen and coal passers enough to handle the fires properly, remove ashes, and see to the normal operation of the boilers, and one or two handy men to do the odd jobs that are always requiring attention.

"The foregoing make up all the actual outlay required to produce the steam for heating, but it is customary also to consider depreciation, repairs, etc., which amount to 12 per cent. of the original cost of the plant.

"If the pumps required by the plant and the fans are steam-driven and the steam is turned into the heating system no special account need be taken of the amount used, but if they are motor-driven a further sum must be added to the foregoing cost: that for the electric current consumed, whether this is obtained from a plant in the building or from a central power plant."

In reference to actual practice the authors thought it might be of interest to take two different buildings of about the same type and size, one having its own power plant and the other operating a heating plant only.

OFFICE BUILDINGS.

In a modern office building equipped with a vacuum system, temperature control, low pressure boilers and smokeless furnaces the theoretical fuel consumption is as follows:

Direct radiation 60,850 sq. ft.

The average outside temperature for the seven heating months of 1911 and 1912 was 33.6 deg.; therefore, the theoretical number of hours that radiators would be turned on would be $70 - 33.6 = \frac{36.4}{80}$ or 45½ per cent. of 210 days $\times$ 24 hr., which would be 2,293 hr. Therefore the steam required for heating would be $\frac{60{,}850 \times 225 \times 2{,}293}{961} = 32{,}668{,}091$ lb. To this should be added the loss through piping which is covered with 85 per cent. magnesia, and we have estimated this to be 3 per cent. of the total, which would make the total loss by radiation, 33,648,133 lb.

For ventilation there are the following units:

1 unit delivering 32,420 c.f.m. at an average rise of 26.4 deg. for 20 hr. per day.

1 unit delivering 18,400 c.f.m. at an average rise of 28.4 deg. for 20 hr. per day.

1 unit delivering 33,860 c.f.m. at an average rise of 51.4 deg. for 10 hr. per day.

1 unit delivering 19,500 c.f.m. at an average rise of 76.4 deg. for 10 hr. per day.

The steam required for above service would be as follows:

$$\frac{\overset{\text{R.}}{32{,}420} \times \overset{\text{M.}}{26.4} \times \overset{\text{HRS.}}{60 \times 20} \times \overset{\text{DA.}}{180}}{55 \times 961} = 3{,}497{,}717 \text{ lb. of steam}$$

$$\frac{18{,}400 \times 28.4 \times 60 \times 20 \times 180}{55 \times 961} = 2{,}135{,}521 \text{ lb. of steam}$$

$$\frac{33{,}860 \times 51.4 \times 60 \times 10 \times 180}{55 \times 961} = 3{,}556{,}212 \text{ lb. of steam}$$

$$\frac{19{,}500 \times 76.4 \times 60 \times 10 \times 180}{55 \times 961} = 3{,}044{,}147 \text{ lb. of steam,}$$

making a total of 12,233,597 lb. of steam for ventilation, which, added to that required for heating, makes a total of 45,881,730 lb. of steam, which, when burning screenings and evaporating 6 lb. of water per pound of coal, would take $45{,}881{,}730 \div (6 \times 2{,}000) = 3{,}823$ tons.

The actual fuel consumption per month was as shown in the accompanying table.

ACTUAL FUEL CONSUMPTION IN OFFICE BUILDING.

	Theoretical Tons	Actual Tons	Outside Temperature, Degrees	Average Wind Velocity, Miles
October	248	301	53.3	12.8
November	542	573	35.4	16.9
December	547	468	35.0	14.4
January	783	913	11.9	14.2
February	759	656	21.8	14.4
March	640	661	28.8	13.5
April	338	286	48.8	16.5

It will be noticed from this table that, during the months of November and December, the temperature was about the same, but the wind velocity decreased about 15 per cent. and the fuel consumption about 18 per cent. The difference between the months of April and October, of course, is not consistent, but as the engineer had no means of weighing the coal as it was put into the boilers the figures given per month might not be absolutely correct.

The cost of operation of this heating plant is as follows:

Coal, 3,858 tons @ $2.37	$9,143.46
Removing ashes	554.00
Oil, waste, and packing	160.00
Repairs	100.00
Labor	4,500.00
Electric current for vacuum and boiler feed pumps	429.00
Water, approximately	200.00
Interest and depreciation, 10 per cent	2,892.00
	$17,978.46

making the actual cost of producing steam $\frac{1{,}000 \times \$17{,}978.46}{3{,}858 \times 6 \times 2{,}000}$ = 38.8 cents per 1,000 lb., and if the fuel for water heating were added in there would be an additional expense of $2,883 for coal and $174 for removing ashes, making the total expense per year $21,035,46. This would bring the cost of steam per 1,000 lb. down to $\frac{1{,}000 \times 21{,}035.46}{5{,}074 \times 6 \times 2{,}000} = 34.6$ cents.

In another building, almost a duplicate, having its own electric generating plant and hydraulic elevators, the heating load would be about as follows: 68,000 sq. ft. direct radiation, at

$$\frac{68{,}000 \times 225 \times 2{,}293}{961} = 36{,}506{,}660 \text{ lb. of steam.}$$

The pipes were covered with moulded asbestos, so loss through same may be estimated at 4 per cent., which would bring this load up to 37,946,926 lb.

For heating water we may estimate the load to be about the same as in the previous building, which required 14,600,000 lb. of steam, making a total of 52,546,926 lb.

The cost of operation is as follows:

6,275 tons No. 4 washed nut @ $3.00	$18,825.00
Removing ashes	890.00
Oil, waste, and packing	470.00
Water	2,407.00
Lamp renewals	486.00
Labor	9,320.00
Interest and depreciation, 10 per cent	7,000.00
	$39,398.00

To obtain cost of steam for heating, the following deductions must be made:

For 644,742 K.W. generated:			
Fuel (@ 49 lb. steam per K.W.)	$6,551.00		
Water	249.00		
Lamps	486.00		
Ashes	310.00		
Oil, waste, and packing	100.00		
Labor	1,884.00		
Interest and depreciation	3,000.00		
	$12,580.00	$12,580.00	
For Elevators:			
Coal	$7,712.00		
Water	257.00		
Ashes	364.00		
Oil, waste, etc	300.00		
Labor	2,700.00		
Interest, etc	1,000.00	$12,333.00	$24,913.00
			$14,485.00

which would be the additional cost for heating.

If this were taken at the same cost rate as the previous building, the cost of heating would be 52,566,926 lb. of steam at 34.4 cents per 1,000 lb., or $18,083.00. Therefore, the saving on cost for heating is: $18,083

14,485

$3,598

However, this does not represent the actual saving shown by the operation of this plant. The saving would be as follows:

Cost of heating without plant	$18,083.00
Revenue for K.W. sold	25,855.00
Revenue for K.W. for public lighting	9,928.00
Cost of elevator service	12,333.00
	$66,199.00
Less cost of operation	39,398.00
Saving	$26,801.00

VENTILATION.

The cost of operation of a ventilating apparatus varies greatly with the installation; but under normal conditions where the system is designed to deliver air at a temperature of 75 deg., taking outside air at an average of 35 deg., the steam required will be $\frac{1,000 \times 40}{55 \times 961} = 0.75$ lb. per 1,000 cu. ft.

The power will be $\frac{\text{C.F.M.} \times 9 \times \text{pressure in oz.}}{33,000 \times 50}$, which for 1 oz. pres. = 0.5454 h.p. per 1,000 cu. ft.

The horse power required varies directly with the pressure.

HOT BLAST HEATING.

For estimating the volume of air required the following formula is found to be quite accurate:

H = total B.t.u, to be supplied per hour.

D = difference in temperature between room and incoming air.

F = cu. ft. of air per lb. at the temperature leaving coils.

V = cu. ft. per min. required.

$$V = \frac{F\,H}{.2375\,D \times 60} = \frac{F\,H}{14.25\,D}.$$

DISCUSSION.

Mr. Hart: In the table are ten residences, that I took at random, and the data supplied was furnished by the owners. The data obtained might not be absolutely correct, but I think that the quantities given are fairly close. They do not, however, check up at all with the theoretical fuel consumption, the reasons for which I have left for open discussion. Of course in a residence we do not know whether all the rooms are heated, or not all the time, and there may be considerable radiation, such as window radiators under seats, that do not give off anywhere near the B. t. u. estimated in the theoretical calculations.

The method in computing the apartment building is practically the same as for residences, but the results of actual

installations given for five typical flat buildings in Chicago, the usual type of flat building that is put up to sell, wherein it is estimated that they ought to burn about three tons per hundred square feet of radiator surface per season, the results show in these five buildings that the average is nearer six tons per hundred.

The information given for schoolhouse heating was supplied by Mr. Patterson, who is acting chief engineer of the school board in Chicago, and the results given here I have not checked up, but he comes to the conclusion that 0.18 pound per season per cubic foot of air warmed per hour is a fair average. It is interesting to note the slight difference in coal consumption between the anthracite and bituminous coals.

Under office buildings, Mr. Hubbard, as chief engineer for D. H. Burnham & Co., who does a great deal of calculating along the line of estimating the cost of operations of plants, has given us his general practice for this calculation. In reference to actual practice the author thought it might be of interest to take two different buildings, of about the same type and size, one having its own power plant, and the other operating its heating plant only, for the purpose of comparison theoretically. The cost of operation, taken in modern buildings fitted with a vacuum system, temperature control, low-pressure boiler, is given in the paper.

President Hale: This paper is the result of investigations made by the Illinois Chapter, and is the résumé, you might say, of the discussion brought forth in one of the Chapter meetings, which shows the possibility of getting papers before the annual and semiannual meetings of the Society from the work done at the meetings of the Chapter from time to time during the year. The paper is before you for discussion, and, as stated in the former case, all visitors, as well as members, are invited to participate in questions.

Mr. Lynd: I would like to refer to the calculations for indirect radiation. It is customary to figure for rough calculations, and a great many manufacturers recommend that it be used in their printed matter, that 50 per cent. more heat be figured for a given space where indirect surface is used than where direct surface is used. It is also a fact that in warm-air furnace work under ordinary conditions the air is taken into

the furnace at zero and sent into the rooms at 140 degrees, and the temperature of the rooms is maintained at 70—that is, just twice as much heat will be required to offset the heat loss. Now, Mr. Hart calculates that three times as much heat is required by indirect radiation as with direct radiation. I would like to know which of these statements is correct, or if Mr. Hart can reconcile them.

Mr. Weinshank: The same question about radiation. Mr. Hart claims that it has been proven that it takes about three tons per hundred square feet of radiation, which, on the basis of $3.00 per ton, would be $9.00, or 9 cents per square foot for the season. I have some data from a central heating plant for the actual cost of supplying steam per square foot. The actual cost is 15 cents per square foot for the season, 180 days. How Mr. Hart claims it to be on a 9-cent basis, I cannot see it.

President Hale: Any further questions to be asked Mr. Hart in connection with this paper—any remarks to be made, or suggestions? I noted a number of the members making pencil notes on their copies. Evidently they have something to ask, but are not ready.

Mr. Weinshank complained of the fact that papers did not reach the members long enough ahead of the meetings to be read and discussion prepared.

President Hale: That just carries out the thought that has been expressed so many times, that the members writing papers, or sending in discussions, do not get them in in ample time to have them published and sent out to the members in advance. It is true that some of these papers were received within the last thirty days; the Secretary tells me that all were received within thirty days. It takes time to prepare them for the press. They have to be investigated by the Publication Committee, and it is therefore very necessary that the papers should be in sixty days before the time they are to be ready at the meeting. As I said this morning, it is to be hoped that members will send in their papers as early as possible; if possible, 60 days in advance. Are there any further questions to be asked of Mr. Hart in reference to his paper?

Professor Hoffman: The author states that "the average difference in temperature is 35 degrees to 70 degrees, equals 35 degrees." I presume that is intended to mean that 35 degrees

was found to be the average temperature for the year. Apparently nothing is stated to that effect, but if it were stated in here it would be so much better. It would be very clear.

Mr. Lynd: I would like to ask the correct position of the decimal point in the fan formula.

President Hale: I don't know why someone has not called attention to the fact that 225 B. t. u. is used as the heat loss, whereas it has been customary to use 250, and, in another paper of to-day, by Mr. Taggart, 250 is taken into consideration, and calculations could not be correct if 250 were right and 225 were wrong. Would like very much to learn from Mr. Hart why he took the 225 B. t. u. heat loss.

Mr. May: It seems to me that, in application of a rule, this old rule three tons per hundred feet of radiation has been generally applied to direct radiation. Now, when you try to apply that same rule to indirect radiation, where the conditions are so changeable, it seems to me that it would be rather radical to apply one of the old formulas which was primarily established for direct radiation only. I simply want to say that an investigation into several different installations has proven that, with direct radiation alone, the old rule, three tons per hundred square feet steam, checks out very closely when you consider the mean temperature of the heating season. For example, the mean for 33 years (seven heating months) is 38 degrees; that is the mean winter temperature, and, figured on the basis of three tons per hundred feet of radiation, which checks out very closely with the actual requirements, figuring on the 38 degrees heat, and also taking the mean at different sections of the country. The *Scientific American Reference Book* has a table which gives for the United States and varying points, the mean or normal temperature for every month of the year, and, taking the seven months during which heat is actually required in a great many parts of the country, the average comes fairly close to 35 or 40 degrees. My main point, going back to it, is that I do not think this should be compared with a rule which has been in use primarily for one thing and tried to apply to an altogether different condition.

President Hale: If there are no further questions, Mr. Hart will be requested to reply to those which have been asked by the five members.

Mr. Hart: In reply to Mr. Lynd's remarks, I think I can answer Mr. May at the same time. I have never made any actual tests on the heat units given off per square foot of direct or indirect radiation, but, with indirect radiation, I have always considered it usual practice to estimate the heat loss at 450 B. t. u. per square foot per hour with incoming air at about 35 degrees.

In reference to the amount of radiation, it is a general practice to install 50 per cent. more indirect radiation for heating a room than direct. That being the case, it is evident that theoretically it would take three times as much coal to heat that room with indirect as it would direct. However, if you will look at the table down here, where some of these houses are heated with indirect radiation, it will be seen that in actual practice they do not burn anywhere near that much coal. Why they don't I am not prepared to say. I thought probably these tests at the research plant to-morrow might enlighten us.

In reply to Mr. Weinshank, the cost of coal taken at $3.00 is rather low, because these calculations are based for residence heating on anthracite coal, and for apartment buildings on Pocahontas coal at a cost of about $4.50 a ton. Now, while theoretically apartment buildings would require three tons per hundred square feet, in none of these five buildings does it run that low. In the first one it runs 6.4 per 100 feet, in the second 5.56, and so on. Again, he speaks of a central heating plant, and he must consider the loss of heat through his long main pipes that are underground. I will state, however, that these results given for these apartment buildings were rather a surprise to me. They were jobs that we did not install, and I don't know who installed them. However, I did check up two jobs that we had installed, that are in very high-class buildings; one building has 7,341 square feet of direct heating surface, heated by two 48-inch by 12-feet tubular boilers, and they burned last year for eight months heating season 215 tons of Pocahontas coal, which figures 2.93 tons per 100 square feet of radiation for the season. The other building contains 5,259 square feet of direct radiation, and is heated by the same-sized boilers, and burned for the eight months 170 tons of Pocahontas coal, which amounts to 3.23 tons per 100 square feet per season.

Mr. Hoffman called attention to the figures of 35 to 70 de-

grees. The average outside temperature in Chicago for the heating season is about 35 degrees, and the minimum about —10 degrees. The usual temperature to be maintained inside is 70 degrees, therefore the average difference in temperature between the outside and inside is 70 degrees, minus 35 degrees, equals 35 degrees, against a maximum difference of 70 degrees to —10 degrees, equals 80 degrees. It is assumed that the radiation would be turned on but a sufficient number of hours to maintain the temperature in the room at 70. In other words, it would be in use 43¾ per cent. of the time of the heating season, and, if you had automatic regulation, that is what would happen, and that is what happened in these two office buildings.

Mr. Lynd called attention to the last equation; the decimal point should be .2375.

In reply to Mr. Hale, taking a basis of 225 B. t. u. per square foot. The heating concern with which I am connected have been somewhat skeptical on taking as a standard 250, because of the various styles of radiators—four-column radiators, 44-inch, 14-inch seat radiators, etc.—and, as a mere precaution, and not having made any actual tests, we have used the basis of 225 as a fair average for a number of years, and I anticipated some discussion on this, and that is the reason that I based these calculations on that number of heat units. I thought perhaps that we could all learn something in open discussion on this point, and probably out at the Research Building to-morrow we can find out how near right that is.

Mr. McDonald: I would like to inquire from Mr. Weinshank as to his statement of the cost of heating at 15 cents, if that is on a flat-rate basis.

President Hale: I am afraid that we cannot continue the discussion between different members on the floor.

Mr. McDonald: I dislike very much to see a statement of that kind go on record without some foundation for it to be based upon. I think Mr. Weinshank's statement ought to be explained.

President Hale: The question was put to the author of the paper.

Mr. McDonald: Still Mr. Weinshank's statement will be a part of the record.

President Hale: On the original proposition, Mr. Weinshank, will you reply to Mr. Hart, and that will put us right.

Mr. Weinshank: I understand, not from one alone, but from two and three different companies who have made a series of tests, and they found that their actual cost of supplying steam to buildings was 15 cents per square foot for the season. They charge 25 in Indianapolis, 26 in other cities, and the smaller cities I understand they charge 20 cents. But the rates I refer to are in large cities, and are the actual cost of supplying steam to their customers.

Mr. McDonald: May I ask, Mr. Weinshank, if that does not include the cost of operating, etc.?

President Hale: Probably overhead charges, etc.

Mr. Weinshank stated it did.

A Member: It seems that this difference may be accounted for by this fact. That these calculations are based on a uniform variation, all the way from the minimum heating requirements to the maximum, and I do not think that heating by steam —direct radiation or indirect—is so perfectly flexible that the cost will vary directly as the heating requirements all the way from the minimum to the maximum. That is based on the requirements for the whole season. Now the cost for the whole season will undoubtedly be more, for the simple reason that you cannot get down to the minimum cost at the end of the season.

Mr. Bolton: This paper is an interesting contribution to a phase of the art of heating which has had comparatively scant attention in the transactions of our Society. Since the scope of the subject is so wide, it is scarcely to be expected that within the limits of a single paper anything approaching a complete presentation of it can be made. The paper, however, rather ambitiously aims at a definition or method of computing the operating cost of heating and ventilating in advance of construction, and the importance and value of accurate information in such a matter must be apparent.

At the outset, the committee, whose conclusion the author presents, concede that their available information is conflicting and unsatisfactory.

It appears to me that this criticism of ascertained facts is rather due to the committee's preconception of what constitutes

the basis of comparison. If the facts adduced fail to support, as they appear to do, the methods advanced, then the source of conflict must be looked for in the method rather than in the ascertained facts.

In residence heating the author advances the method of ascertainment of heat usage during a heating season which, so far as it goes, is theoretically correct, provided, however, that the users of the apparatus fulfill the theoretical assumption of maintaining all the radiating surface in active operation during the period of the heating season. This is just what they do not do, except in unusual instances of negligence, and the wasteful habits which are occasionally found to exist.

Mr. G. L. Hubbard's experience evidently coincides with this statement, since he assumes that an average of 35 per cent. of installed radiating surface is inactive in office buildings.

This element is a considerable factor in other types of buildings, but is reversed in apartment houses, where deliberate wastefulness on the part of tenants appears to have become a settled habit.

An analysis of the table (1) of fuel consumption in ten residences is confirmatory of this view. The discrepancy between the fuel estimated by the author's method, and that actually used, is invariably in one direction, a considerable excess, which varies from 34 per cent. to 130 per cent. over the real consumption.

The largest discrepancies are in those instances where indirect heating forms the largest element; such as instances, *viz.:* Nos. 1 and 9 of steam service, and Nos. 2 and 5 of hot-water service. In these the effect of the original error of assumption is increased by the additional condensation and additional radiation assumed in the method of estimate, and possibly also by the fact that indirect heating is more economically utilized than direct.

When compared on the basis of actual consumption per 100 square feet of equivalent direct radiation, the instances do not show large relative discrepancies, when such probable factors as character of fuel and methods of firing are considered.

STEAM

No.	Direct radiation	Indirect equivalent	Actual fuel-tons	Error of estimate	Tons per 100 sq.ft. per season
1	666	1,080	55	60%	3.1
9	878	2,100	70	124%	2.3
8	1,296	384	45	42%	2.6

(NOTE: No. 1 has no automatic control and the consumption agrees with the estimated rate for direct steam radiation.)

WATER

No.	Direct radiation	Indirect equivalent	Actual fuel-tons	Error of estimate	Tons per 100 sq.ft. per season
2	1,350	1,800	60	130%	1.9
5	1,340	730	45	90%	2.1
10	1,355	240	36	55%	2.2

In apartment buildings the instances cited of this class of heating service, the error of estimation by the author's method is equally apparent, but in the reverse direction, all the ascertained costs being in excess of their estimate of $13.50 per 100 square feet per season. The actual figures are as follows, and, with the exception of instance No. 1, they exhibit a decreasing cost accompanying reduction in size:

No.	Radiation	Coal per 100 sq. ft.	Cost @ $4.50
4	7,076	6.5	$29.25
2	6,000	5.6	25.20
5	3,900	5	22.50
1	3,435	6.4	28.80
3	900	4	18.00

It is difficult to derive any determinate data from these instances in the absence of information as to surrounding circumstances, such as whether hot-water supply is or is not included in the heating work.

More information should be adduced in these connections, because the habits of tenants of this class of building include the opening of exposed windows at night over the radiators, leaving steam full on in unoccupied spaces, opening air valves, etc.

In school buildings the authors recognize the limitations of period of use, and, with the precise character of usage, the estimated figures accord with the recorded results of the three instances adduced.

In office buildings Mr. G. L. Hubbard's statement of his method of ascertainment of cost of heating is of interest, chiefly in its divergence from the method advanced by his fellow-committeemen. His assumption of a proportion of 65 per cent. of active radiation to total installed is probably an average figure, and his assumption of an evaporation of 6 pounds of water to one pound of fuel, is nearer average conditions than the

author's estimate of 8,000 available heat units per pound of anthracite.

Among his minor elements of cost, that of ash removal at 10 cents per ton of coal is too low, for the instances quoted in the paper show the cost to be at the rate of 14 cents per ton of coal. The average cost in New York City with small anthracite is about 17 cents. In enumerating other charges, he omits reference to supplies, interest, taxes and insurances.

The other instances given by the author are of value, as any such actual figures of cost are of help in the ultimate determination of this question, but I find some omissions and errors in the method of presentation of the facts.

The first instance is a low-pressure system, which includes the operation of a vacuum system, apparently involving the use of power-driven vacuum and boiler-feed pumps, which, if eliminated, would reduce the cost by nearly $600. The cost of operation of this plant, *viz.*, 39 cents per 1,000 pounds evaporated, is with taxes, insurances, rental value of space, etc., probably in excess of the price of purchased steam service, if such were available. Such a supply would reduce the total required to cover the heating, plus boiler losses, etc., and therefore the instance quoted cannot be regarded as a favorable illustration of economical operation.

Further, the author presents the comparative illustration of a very similar building, having a power generating plant, and apparently exhaust steam heating, and the figures of cost are used by the author in an analysis of the comparative cost of heating.

The divisions assumed for the separate costs of electric and hydraulic power do not appear to have received sufficient study.

The work of heating is charged with $1,901 for water and $3,000, or more than 40 per cent. of the fixed charges. Only $100 is given as the cost of supplies for the generation of 644,000 k. w. hours, which is inadequate. With such due addition to the power costs, and including the operation of all the power auxiliaries involved in high pressure steam, also adding such fixed elements as insurances, taxes, etc., it is probable that the cost of current would be in excess of the two cents per kilowatt hour as presented.

The stated cost of elevator operation, on an electrical basis

at the same price, would afford, at 4 kilowatt hours per car mile at 15 car miles per diem, the services of 34 elevators. It is at least questionable, therefore, whether the power plant is a paying proposition at the costs apportioned, and in New York City it would probably pay to abandon this plant in favor of purchased supplies of steam and electricity, at 45 cents per 1,000 pounds steam, and 3 cents per kilowatt hour for electric service for lighting and elevator service.

It appears that in this building the electrical services are charged to tenants, and debited to the building operation at the average price of 5½ cents per kilowatt hour, a practice which has not been adopted, so far, in office building operation in New York.

But the revenue thus derivable cannot properly be utilized in the manner adopted by the author to effect an apparent saving in the cost of heating operation, because it could just as well be secured with a purchased service of electricity.

CCCXXIV.

EXPERIMENT IN SCHOOL ROOM VENTILATION WITH REDUCED AIR SUPPLY THROUGH INDIVIDUAL DUCTS.

BY FREDERICK BASS.*

It is a well-known fact among ventilating engineers to-day that the practice of ventilating has, in most cases, little, if any, scientific physiological basis. The mechanical principles governing the selection and types of fans, the relations of pressure and velocity of flow of air in pipes of various sizes, the transference of heat and other purely mechanical and engineering factors are quite well appreciated and applied. But the fact that the physiological factors are fundamental and primary and that the mechanical principles are secondary seems for many years to have escaped general recognition, and it is only in very recent years that engineers have come to realize that a knowledge of applied mechanics is but a small part of the problem of ventilation and that physiological and psychological demands are of prime importance.

During the past few decades engineers have been designing apparatus to deliver into the rooms to be ventilated a certain fixed quantity of air, the object being to keep the carbon dioxide content down to a prescribed minimum, usually from 8 to 14 parts per 10,000. It has been known that carbon dioxide itself is not harmful in quantities ordinarily found and that its effects on the human organism are not noticeable until it rises to perhaps 300 parts per 10,000, a figure never approached in practice. But the carbon dioxide has been used as an indicator of so-called "impurities" in the air. Laboratory experiments by many investigators have failed to demonstrate these impurities in chemical terms, but the human nose has conveyed the impression to the human brain that something was wrong when the carbon

* Non-Member, University of Minnesota, Minneapolis, Minn.

dioxide in an unventilated, occupied room rose above the figures mentioned. Other sensory nerves have corroborated the impression.

In the laboratory experiments just alluded to it has been amply demonstrated that a human being may suffer severely from stagnant air, especially when its temperature and humidity were high, while with air in motion and of moderate temperature and humidity, although with carbon dioxide over 200 parts per 10,000 and oxygen below 19 per cent., no discomfort or adverse physiological results appeared. If these laboratory experiments were corroborated under ordinary working conditions it would be at once evident that the standard ventilating practice of the present is unsound and probably inefficient, since so little attention is given to the conditioning of the air and its control in the occupied space, while overemphasis is placed on mere quantity.

In the experiment described in the following it was attempted to so arrange the ventilation that the quality of the air of the room with respect to humidity, temperature and odors would be under control and further to so arrange the distribution of the air that each occupant would be conscious of the moving air. The usual crowd odor was neutralized by means of ozone. It was impossible at times to operate the apparatus to its full efficiency on account of insufficient attendance; the humidity was variable throughout the experiment, whereas it would have been desirable to keep it constant, and there were a number of observations of interest, such as the carbon dioxide content of the room at various points, which might have been used if taken. Other shortcomings of the work are apparent too, but the results are nevertheless interesting.

The system was so operated during three weeks that the air delivered to the room was exhausted, not into the outside air, but into a duct leading to the fan delivering the air to the room; in other words, the air was rotated and used over and over again. Between the exhaust and delivery fans there was an ozone generator delivering approximately one part of ozone per 1,000,000 parts of air. The ozone generator was calibrated by the potassium iodide method by Mr. H. A. Whittaker of Minneapolis. A full description of the apparatus is as follows:

DESCRIPTION OF VENTILATING EQUIPMENT

A room was selected on the first floor of the Jackson School in Minneapolis. The air to be delivered to the pupils in the room was taken in through a window in the basement and passed over two Vento radiators to a Warren Webster air washer and humidifier, thence to a heating coil, from which the air was blown to the outlets in the room by means of a Sirocco blower. These apparatus were loaned through the courtesy of Warren Webster & Co. and American Blower Co. The main

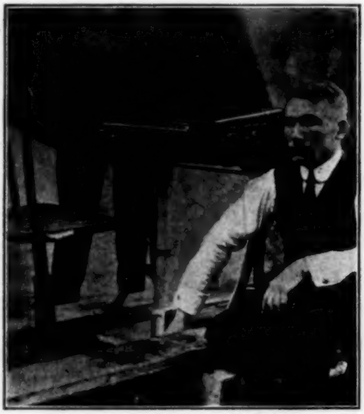


FIG. 1.—TYPE OF ORIFICE FIRST TRIED

FIG. 2.—TYPE OF ORIFICE ADOPTED

duct from the blower was carried along the ceiling at one end of the basement room immediately below the room in which the pupils to be the subjects of the experiment were located and from it three ducts were extended parallel to the rows of desks. From these ducts the air was carried through 2-in. risers extending through the floor to each desk in the room above, at which points it entered the room through funnel-shaped orifices.

Previous experiment with a single desk and funnel ventilator had shown that, with 7 cu. ft. of air per minute, the head and shoulders of the pupil could be surrounded by air moving at a velocity sufficient to carry away the breath but still not great

enough to be objectionable. In this way it was made certain that each pupil would actually receive the air both in quantity and quality that was desirable, and, by means of a number of openings in the ceiling, through which the air was drawn by an exhaust fan, it was made equally certain that the exhaled air would be immediately removed from the room.

In the preliminary experiments to determine the best type and location of orifice for admission of air to the room, the first form experimented upon was an elongated orifice or slit in the front edge of the desk. Fig. 1 shows a view of this orifice. The funnel type shown in Fig. 2 gave a much better distribution of

FIG. 3.—ARRANGEMENT OF SUPPLY DUCTS AND DESKS.

air and for other reasons was much better adapted for use in a school room and it was accordingly adopted. Fig. 3 shows the school desks themselves with a number of these orifices in position. Fig. 4 is a view in the basement room below the room fitted out, and shows the heating coils, air washer, blower, regulating devices, as well as the system of pipes used to distribute the air to the desks. In addition to the inlets at the desks, two lines of 6-in. pipes with 1-in. x 2-in. rectangular orifices 1 ft. apart were placed along the two sides of the room at a height of 6 ft. from the floor. Approximately 50 cu. ft. of air per minute was blown into the room through these openings.

The cumbersome appearance of the apparatus is due to the

fact that the air washer, blower, and heating coils were loaned and were larger than necessary. The direct radiation in the room, the temperature of the entering air, and the temperature of the water in the air washer were automatically regulated by thermostatic control put in by the Johnson Service Co. The piping and sheet metal work was done by the Waterman-Waterbury Co. of Minneapolis. In addition to the foregoing described

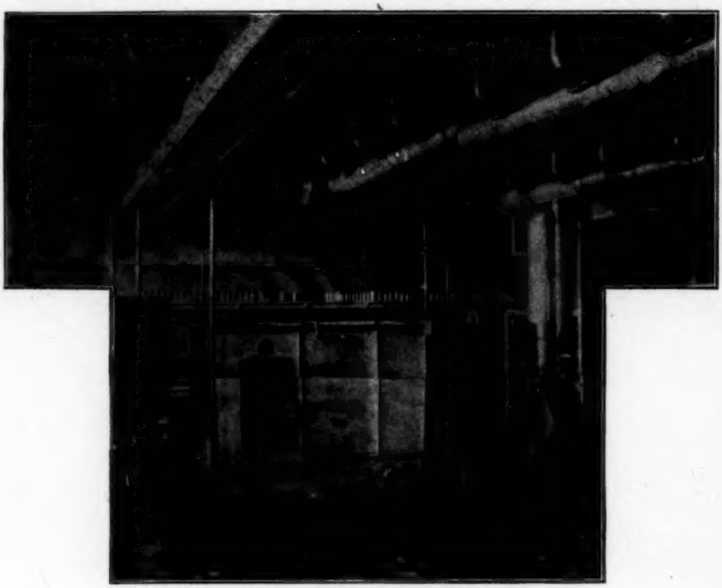


FIG. 4.—VIEW OF APPARATUS IN BASEMENT.

apparatus an ozone generator was installed by A. R. Willford, Minneapolis. The ozone was generated by an electrical current of 9,000 volts. It was forced into the pipe system by a small Sirocco fan. The ozone was introduced into the room in the proportion of one part to 1,000,000 parts of air. The heating of the building was performed by direct radiation controlled by Johnson thermostats.

PHYSIOLOGICAL AND PSYCHOLOGICAL TESTS

A group of pupils in the room described was selected for physiological and psychological tests. A control group of chil-

dren of the same grade and general characteristics of race and living conditions was selected in a nearby school, referred to hereinafter as the Adams School, where an ordinary fan ventilating system delivering about 30 cu. ft. of air per pupil per minute was installed. The test group was supplied with about 8½ cu. ft. of renewed air per capita per minute. The control group had outside air. During the period the characteristic odor of ozone was perceptible in the test room and apparently kept the air in an acceptable and pleasant condition, for on one occasion the motor-blower set which forced the ozone into the air current was temporarily disconnected and the teacher, not knowing what had happened, within half an hour felt it necessary to open the windows and to call attention to the marked change in the air.

The description of the experimental work may be divided into three divisions as follows: (A) Physical records, including measurements of air velocities and volumes, temperature records and humidity observations; (B) Physiological observations, including bodily temperatures and blood pressures; and (C) Psychological tests, including division, substitution, and motor tests. The manipulation of the plant was performed and recorded by Mr. W. J. Bingen, a post-graduate student in the College of Engineering; the physiological observations were made by Dr. E. J. Heunnekens, and the psychological work and computation were performed by Mr. H. D. Kitson, a post-graduate student in the College of Science, Literature and the Arts of the University of Minnesota.

PHYSICAL RECORDS

The performance of the fans and other apparatus had been determined previous to the beginning of these experiments by Mr. E. J. Lewis, a mechanical engineer of Minneapolis. The distributors on the desks were controlled by means of individual dampers, so that approximately 7 cu. ft. of air per minute was supplied through each. This rate was continued throughout the experiment as well as for two weeks before. The temperature was recorded by a Draper's self-recording thermometer and the humidity of the room was observed each day at 10 o'clock a. m. by the use of a Hygrodeik hygrometer which had been cali-

brated. It was found that this instrument is easily accurate to 1 per cent., provided the wick is kept clean. Both instruments were located on a shelf on an inside wall about 6 ft. from the floor.

It will be seen from the table in the following that the average temperature of the test room in the Jackson school was 68.8 deg. F. and that the average relative humidity was 32.6 per cent. during the test. During the first week in which psychological observations were made the average temperature was 68.4 deg.

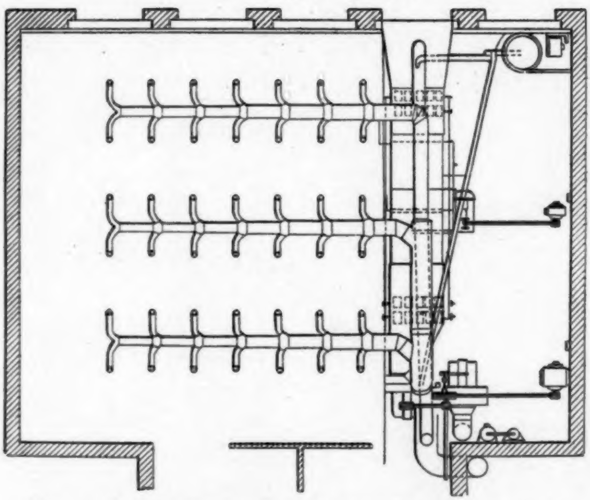


Fig. 6.—Basement Plan Showing Location of Apparatus and Ducts on Ceiling.

F., and during the latter week 68.8 deg. F. The relative humidities were 35.6 per cent. and 29.8 per cent., respectively. The highest average daily temperature recorded was 71.9 deg. F. and the lowest 65.1 deg. F. The highest humidity observation was 50 per cent. and the lowest 25 per cent.

The temperature at the Adams school was kept at approximately 68 deg. F. No humidity records were kept, but, in all probability, these were not materially different from those in the Jackson school, since during the three weeks previous to the first test week the humidity in the Jackson school averaged 33.3 per cent. when outside air was supplied, as against 32.6 per cent.

during the three weeks when the renewed air was supplied, which would seem to indicate that the revolving of the air did not greatly affect the humidity in this experiment.

TABLE OF AVERAGE TEMPERATURE AND HUMIDITY IN TEST ROOM.

Date	Average Temperature, Degrees F.		Average Relative Humidity, Per Cent.		Inside			
					Average for Week		Average Three Weeks	
	Inside	Outside	Inside	Outside	Temp.	Hum.	Temp.	Hum.
Feb. 18	70.7	35	35	73	....	....	....	....
19	67.7	47	37	73	....	....	....	....
20	68.4	33	41	81	....	....	....	....
21	68.3	21	....	94	....	....	....	....
24	69.1	3	35	72	....	....	....	....
25	67.9	7	32	68	....	....	....	....
26	68.8	19	....	93	....	....	68.4	33.3
27	....	9	37	56	....	....	....	....
28	67.7	3	....	70	....	....	....	....
Mar. 3	66.8	—3	36	76	....	....	....	....
4	67.5	16	29	56	....	....	....	....
5	68.6	17	27	94	....	....	....	....
6	68.5	18	25	75	68.5*	29.8*	....	....
7	69.3	10	32	54	....	....	....	....
10	70.0	38	38	72	....	....	....	....
11	70.4	30	32	83	....	....	....	....
12	71.9	37	38	73	....	....	....	....
13	70.8	50	35	67	....	....	....	....
14	69.3	44	36	84	....	....	....	....
17	67.3	13	40	60	....	....	....	....
18	68.2	24	37	76	....	....	....	....
19	68.5	46	50	63	....	....	....	....
20	68.4	47	35	87	....	....	68.8	32.6
21	65.1	17	31	48	....	....	....	....
24	67.9	29	35	100	....	....	....	....
25	69.2	33	40	72	....	....	....	....
26	68.8	20	42	87	68.6*	35.6*	....	....
27	69.4	21	33	54	....	....	....	....
28	67.6	19	28	68	....	....	....	....

* Tests made during these weeks.

PHYSIOLOGICAL OBSERVATIONS

The physiological observation included observation of temperature and blood pressure during two weeks, one immediately preceding and the other during the last week, when the air of the test room was rotated. They were made on 10 children in the morning and 10 in the afternoon, the children being tested twice on the first test week and three times during the second test week. Each child was tested at the same hour throughout the five tests, the morning

measurements being made from 9:45 to 10:30 o'clock, the afternoon measurements from 1:45 to 2:30 o'clock. This brought them before recess and was done in order that the measurements might not be affected by the excitement resulting from play at recess. The average temperature of the average child for the first week was 98.67, m.v. 0.32; for the last week, 98.46, m.v. 0.28. The corresponding blood pressure measurements were 110.13, m.v. 5.47 and 106.25, m.v. 5.48. The temperature tests showed no appreciable difference. The blood pressure readings showed a difference, however, of 3.8 and is to be regarded as significant when considered in relation to the error of difference, which is 1.7. If these blood pressure tests may be regarded as a fair sample, the chances are only about four in 10,000 that this difference is not significant. It is to be said, however, that the blood pressure tests have a low coefficient of correlation, that for the first and second days being 0.54, for the last two days 0.56, using the method of unlike signs. This low correlation casts doubt upon the reliability of these results, as it indicates a pronounced individual variation under the same conditions. On the other hand, the difference is somewhat more significant, in view of the fact that the decrease in blood pressure for the three days of the last week took place in 16 out of the 19 cases, and is in the direction opposite to and in spite of the fact that there may have been considerable emotional excitement due to the strangeness of the proceedings during the first week. In spite of this, which might have tended to reduce the blood pressure more in the first week than in the second, there is a decrease of blood pressure in the second week, after the ventilation had been changed.

PSYCHOLOGICAL OBSERVATIONS

The pupils in the room described in the foregoing were tested to determine their mental progress at the same time that they were tested physically. It was important in the latter tests to eliminate the effect of increased facility which would be acquired by repetition, also to allow for fatigue which would have a tendency to reduce the amount of work the longer it continued. In order to isolate the effects of ventilation, the control group of pupils was chosen in an adjoining school, so that the average

of the tests in the control group would be practically the same as that in the test group. The control group was tested in the same manner and for the same periods as was the test group, only a week later.

It was assumed that the two groups were equally efficient in the activities required, this assumption being based on the similarity of their averages in the first series of tests. Both groups averaged the same within 1 per cent. The work of the control group was a trifle higher in all the tests of the first series, so the assumption was made that this difference would remain constant, and in comparing the work of the two groups for the second week it was allowed for by deducting the amount of difference. This placed the two groups on the same level at the beginning of the second test week, and it was assumed that any deviation which then appeared in the work of the test group could be ascribed to effects of ventilation change. The tests were given on the last hour of the morning of each day in order to have the effect of the indoor ventilation at its maximum.

Division, substitution, and motor tests were used in forms to be described shortly. Promptly at 11 o'clock a.m. the tests were started, 10 min. being devoted to each activity in the foregoing order. For the division test each child was given a paper upon which were printed 140 problems in short division. The divisors were 6, 7, 8, and 9, used in rotation, and the dividends contained three digits. The numbers were so arranged that each problem came out even with two figures in the quotient. Owing to the impossibility of combining the 9 digits in such a manner as to furnish new problems each day, the same problems were given every day. Careful instructions were given before each of the three tests and two-minute practice allowed in each one the first day so as to permit of slight familiarity and prevent misunderstanding of the instructions. After instructions and preliminary practice the papers were laid face downward on the desks and the children were told to write in the upper left hand corner date, name, age, and birthday. When all had finished the children turned over their papers and the signal was given to start, timing always being done with a stop-watch. At the expiration of 5 min. a signal was given and each pupil drew a line underneath the problem he was then working. This was done in

order to furnish a means of comparing the work of the first 5 min. with that of the last 5 min.

For the substitution test a sheet of paper was given each child containing the letters of the alphabet arranged in two horizontal rows across the top. Underneath each letter was placed some number which lay between 11 and 36 inclusive. These numbers were arranged in chance order. The rest of the paper was covered with 17 rows of squares, 10 in a row, each square containing a number and a space underneath in which to insert the

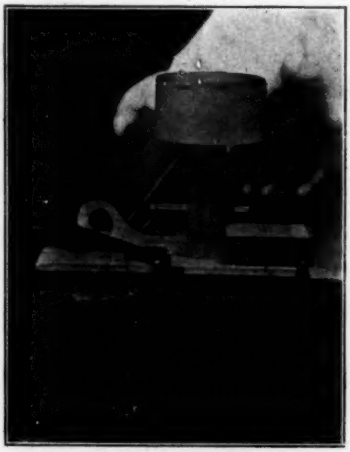


FIG. 7.—THE ERGOMETER USED.

letter which accompanied that number in the key above. The arrangement of the numbers in the key was varied from day to day. The procedure of this test was the same as that for division.

The motor test consisted of the sidewise movement of the index finger described by Bergstrom, with a modification in the manner of holding the rest of the hand in position. It was manifestly impossible to obtain kymographic records of the work of each child, so a simple ergometer, Fig. 7, was devised which would be adapted to group tests and obtain fairly accurate measures of movement against a slight pressure (the wire agitator described below). In this ergometer the finger is inserted

into a hole in a lever, which, when raised up and down, moves a slide back and forth. This slide runs horizontally in a standard which contains a hollow tube 5-32 in. in diameter. On top of this standard, which is 3 in. high, is a round wooden bowl serving as a hopper. When this is filled with steel balls 1/8 in. in diameter they drop down one by one into the tube and rest upon the slide to which the lever is attached. This slide, which is exactly 1/8 in. thick, contains a small hole just large enough to accommodate one of the steel balls. As the slide is moved outward by the raising of the finger-lever it carries out the steel ball from the standard and drops it into a receptacle at the side. Then as the lever is pulled down the slide moves back into position and another ball drops into the 1/8-in. hole. The standard is mounted on a thin base and clamped to the right side of the desk, with about 2 in. projecting beyond the edge of the desk. On the under side of the base is a small ledge upon which the middle finger rests. The forearm rests upon the desk. At the conclusion of the test period the receptacles which catch the balls were collected and their contents weighed, from which it could be determined how many times the child raised his finger the required height.

Since the balls tend to clog at the mouth of the tube a wire extending through the bottom of the hopper into the top of the finger-lever agitates the balls with every movement of the finger. Where a short test is made, however, a vertical brass tube 2 ft. in length replaces the hopper and the wire may be dispensed with. This arrangement affords a movement that is practically without friction.

It is to be noted that the structure of the apparatus compels the child to raise his finger to a certain height in order to have the movement counted. Every upward stroke of the lever must be high enough to carry the slide beyond the edge of the standard or the ball will not drop. On the other hand, every downward stroke must bring the lever clear down to the base or the hole in the slide will not lie underneath the hole leading from the hopper. This regulating of the lift insures a movement of the finger throughout a wide amplitude, and brings about a fatigue effect which cannot be secured by only a moderately high lift.

This instrument, though not possessing the refinements of the Bergstrom ergograph, nevertheless lent itself very satis-

factorily to the present experiment. It is easy to adjust and easy to operate; can be adapted to any size hand by using an aperture in the lever farther from or nearer to the axis of the lever. Furthermore, the element of interest is always present—an important desideratum in dealing with children. It is made of hard maple and can be manufactured for fifty cents.

Various modifications of method can be employed; the time can be divided into several periods by the use of different receptacles. In the present experiment the record of each test was divided into two parts by the use of two differently colored boxes which were shifted at the end of 5 min., thus securing a measure of the first 5 min. work to be compared with that of the last 5 min.

The method of scoring was as follows: In division, every correct solution was given a value of 3. For an error in the first figure of the quotient 2 was deducted, and for an error in the second figure 1 was deducted. For every example omitted 1½ was deducted. Under this system of scoring the highest score attained by any individual during a ten-minute period was 335, and the lowest 10.

In substitution every square correctly filled counted 1; for each substitution omitted 1 was deducted. The highest score attained by any individual during a ten-minute period was 144; the lowest 24.

In the motor test scores were obtained by weighing the total number of balls dropped by each individual and dividing by the weight of the ball. The highest score made in 10 min. was 1,093; the lowest 123.

The tests were chosen with a view to selecting activities of as varied nature as possible, so that there might be several chances of detecting ventilation effects, and, if they were discernible, that they might be observed from several angles. That this end was attained is evident from the comparatively low correlation of the tests with each other. The work of the group in division correlates with their work in the motor test by 0.06; substitution with motor, by 0.49; division with substitution, by 0.36 (using the method of rank differences). These low correlations show that the functions exercised by the three tests are quite diverse. Division work requires a high type of selective thinking and good memory for multiplication tables. The

motor test measures voluntary ability to move the finger rapidly and continuously. Success in the substitution test requires quickness of perception and the ability to adjust oneself rapidly to new conditions. Inasmuch as the arrangement of the numbers in the key was varied every day, the child was obliged, in addition to adjusting himself to the new arrangement, also to work against the habit he had formed the day before. All three tests require close attention, and in the substitution and motor tests there is opportunity for considerable economizing of effort by the gradual elimination of useless movements.

The value of the tests as constant measures of the work of one child relative to the work of another is indicated by the following table of reliability coefficients, computed by the method of rank differences:

CORRELATIONS IN WORK OF THE CONTROL GROUP.

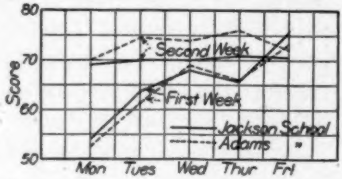
		No. of Cases
First and second days' work in division	0.91	25
Fourth and fifth days' work in division	0.90	..
First and second days' motor work	0.87	19
Third and fourth days' motor work	0.89	..
First and second days' work in substitution	0.83	28
Fourth and fifth days' work in substitution	0.75	..

Inasmuch as the substitution test seemed least reliable of the three, the first day's work in this test was compared with that of the tenth day, and a correlation of 0.77 was found. These high reliability coefficients indicate that the tests are good tests.

Individual differences in performance were great, but the extremes were similar in each group, as shown by the following table:

	First Week		Second Week	
	Test group	Control group	Test group	Control group
Division—				
Lowest score	10	11	29	26
Average score	98.1	99.9	160.2	125.4
Highest score	215	242	335	309
Substitution—				
Lowest score	35	32	24	24
Average	65.3	64.3	70.1	73.3
Highest	119	107	144	129
Motor—				
Lowest score	164	123	154	194
Average	423.3	440.4	519.9	549.2
Highest	708	784	850	1,090

From this examination of the tests it appears that they are admirably suited for measurements of work in ventilation effects. Their value in use with groups is evident from the tendency of each child to retain the same rank in the group in successive tests. Their value as group tests is further shown by the similarity with which the two groups worked, as will appear



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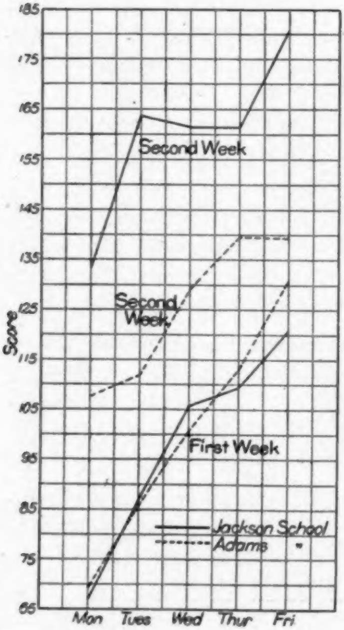

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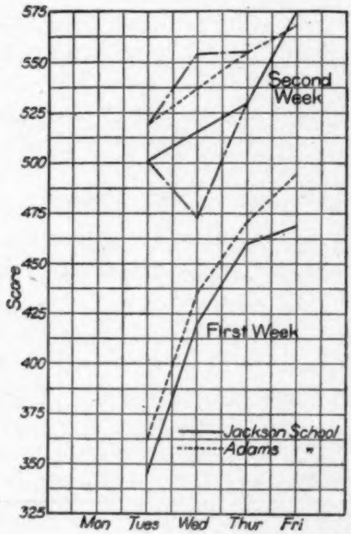

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1. Curves Showing Record of Division Tests. 2. Curves Showing Record of Substitution Tests. 3. Curves Showing Records of Motor Tests.

in the results. In addition to the marked similarity of the averages in all three tests, there was a corresponding similarity in extremes. The same test was preferred by an equal number in each group, and the effects of practice and fatigue were almost exactly the same upon both groups.

The tests measure functions that are quite diverse, as the low correlations indicate. This makes them especially valuable in measuring effects the exact nature of which is not known. It is further evident that the different tests also check each other as to effects of subjective disturbances. It is to be regretted that the division results were injured by interference, still the clearness with which this interference is shown is excellent evidence of the delicacy of the test.

After eliminating the records of all children who were absent on any of the test days and who were thus deprived of practice, together with one who was pronouncedly feeble minded, and thus unable to do some of the work, the number of records finally used out of the test group was reduced to 28 for each division and substitution. The number of motor records used out of the test group was further reduced to 17 owing to the fact that some of the children experienced difficulty with their machines while others broke them. Although these were furnished new machines, each child working steadily, still it seemed advisable to use only the records of children who retained the same machines throughout the tests. The control group was reduced in the same manner to 25 for division, 28 for substitution, and 19 for motor. The total amount of work done each day by the average child is as follows:

TEST GROUP WITH VENTILATION CHANGED

	Mon.	Tues.	Wed.	Thur.	Fri.	Total	P. E.
DIVISION:							
March 3–7	67.3	86.8	105.5	109.6	120.8	490.	154.
March 24–28	133.7	163.7	161.5	161.4	180.7	801.	220.
SUBSTITUTION:							
First week	54.	63.7	68.	65.6	75.2	326.5	54.4
Second week	69.1	70.	70.	71.	70.8	351.	64.9
MOTOR:							
First week	Omitted	354.4	420.	459.3	468.5	1693.2	295.3
Second week	Omitted	501.	473.3	530.6	574.6	2079.5	304.5

CONTROL GROUP WITH VENTILATION UNCHANGED

DIVISION:							
March 10–17	69.5	86.	100.6	112.9	130.9	500.	147.4
March 31–April 4	107.3	111.7	129.1	139.4	139.5	627.1	186.4
SUBSTITUTION:							
First week	52.5	61.2	68.8	66.	73.2	321.7	46.2
Second week	69.8	74.7	73.9	75.9	72.3	366.6	69.9
MOTOR:							
First week	Omitted	362.1	433.	470.7	495.8	1761.6	334.3
Second week	Omitted	518.6	554.	556.7	567.4	2196.7	98.8

For graphic representation of results, see illustrations.

The curves show at a glance extreme similarity in the work of the two groups. In view of the similarity of performance during the first week, it is to be expected that the work of the second week will be equally similar unless some new element is introduced. It is, then, in the second week's results that one is to look for possible effects of the change made in ventilation.

The work of the test group differs most noticeably from that of the control group in division. The total score made by the average child for the first week is 490, and for the second week 801. This represents a gain of 64 per cent., while the corresponding gain made by the average child in the control group is only 25 per cent. This enormous difference aroused the experimenter's suspicions, and, upon investigation, it was found that, during the two weeks elapsing between the first and second test-weeks, the teacher had been coaching the children in short division, using as divisors 6, 7, 8, and 9. The curve shows the results. The control group began the second week's work in division at some distance below the mark of efficiency attained at the end of the first week, showing a loss in efficiency due to practice. The test group, however, began the second week's work far in advance of the point attained at the end of the first week, showing clearly the effect of the intervening two weeks' practice. The occurrence of this phenomenon, while extremely interesting from a psychological and pedagogical point of view, is most unfortunate for the purpose of this experiment, as it thus becomes impossible to compare the total work done in division of each group.

Inasmuch as the work of each day was divided into two 5-min. periods, it is possible to compare the two groups with respect to their rate of fatigue. Although practice would tend to increase the amount of work, fatigue would act in the opposite direction and the combined effect of these two factors may be measured by a "fatigue index" found as follows: The total score for the week made by each child during the second 5 min. of the tests was divided by his total score for the first 5-min. periods. This was done in the case of 12 children in each group (only that number marking the time periods according to directions). For the first week, both groups had the same fatigue index—0.8125, m.v. 0.11. For the second week the fatigue index for the

test group was 0.7609, m.v. 0.08, and for the control group, 0.7591, m.v. 0.11. The difference is only 0.0018, and, as its probable error is 0.037, it will be seen that the slight difference is not at all significant. Thus the division results, though not comparable *en gros,* nevertheless, as treated in the foregoing, show no effect of change in ventilation.

The second week's record for substitution shows a difference of 15.6 in the work done by the average child of the two groups. This difference is in favor of the control group. It is to be noted that the difference existing between the two groups at the end of the first week is that between 326.5 and 321.7, or 4.8. Assuming that this difference continued in the second week, the net difference becomes 10.8. The probable error of this difference computed by the formula P.E. of Difference = P.E. P.E. is 17.7. The chances are even that a difference of about 3 per cent. would occur in 50 min., or the chances are 2 out of 3 that there will be some difference in favor of the first form of ventilation. Since 4 days out of the last 5 tested show against the test group under the second condition of ventilation, the chance that it had a slight effect is somewhat increased. Subtracting the daily average difference between the two groups of 0.96 (obtained by dividing 4.8 by 5) the daily record of the last week stands as follows:

	Mon.	Tues.	Wed.	Thur.	Fri.
Control group	69.8	74.7	73.9	75.9	73.2
Test group	69.1	70.	70.	71.	70.8
Difference	.7	4.7	3.90	4.90	1.50
Subtract		.96	.96	.96	.96
Net difference		3.74	2.94	3.94	0.54

As the difference is only two-thirds of its probable error, however, it is not to be regarded as outside of the range of a chance error due to the single week's sampling of the conditions.

A further comparison is made possible by computing the gain or loss made by each individual. This is done by subtracting the total score made by each child during the first week from his score of the second week, or, in case of a loss, vice versa. This shows that out of 28 children in the control group only three actually lost, while out of the 28 children in the test group loss occurred in eight cases. The average gain made by those who gained is also greater in the case of the control group, being 16

per cent., while that of the test group was 13 per cent. This method of comparison is hardly justifiable, however, as it fails to take into account the fact that the control group was slightly superior to the other group at the start and would be expected to gain faster than the test group.

The fatigue index for the first week, computed for 17 children in each group, was the same in both groups—0.896 with a m.v. of 0.099 in the test group average, and of 0.072 in the control group average. Second week, test group 0.933, m.v. 0.15, control 0.883, m.v. 0.10. The difference in the fatigue index of the second week is 0.065. It is possible that this difference may be significant, being a third larger than its probable error, which is 0.037. The fact that this difference, slight as it is, favors the test group is hard to explain, in view of the fact that the total work done by the control group slightly exceeds that done by the test group. It is hardly probable that the difference in fatigue index was not affected in either of the other tests. The only hypothesis that offers any clue is in connection with the peculiar habit-making process involved in this test. It is possible that the control group, being naturally a trifle superior to the Jackson group, were able to adjust themselves completely to this feature during the first week, while the other group might still be showing the effects of this adjustment in the second week. The true significance of this difference can be determined only by further experimentation.

The motor records for the second week's work of the test group show a decided drop on the second day. As this drop is entirely out of proportion to the rest of the curve, it is probable that some constant error entered in—possibly a mistake in weighing the balls which record the finger movements. Omitting the second day's work from both records, the curves follow each other fairly regularly. The following table gives a comparison of the motor work for the three days of each week—Tuesday, Thursday, and Friday.

	Number of Movements made by Average Child			
Control group	Av. 1329	M. V. 291	Av. 1643	M. V. 500
Test group	1273	257	1606	235
	56		37	

The difference in favor of the control group at the end of the first week was 56. Assuming that this difference remained con-

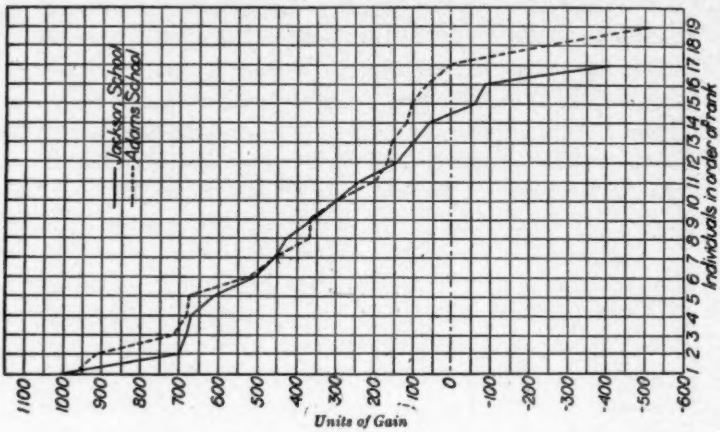
stant in the second week, the net difference between the work of the two groups for the second week is 56—37, or 19, in favor of the test group. This difference is less than 2/10 of its probable error (108); therefore, it can only be attributed to chance.

The greatest difference occurring in any one day is that on Thursday—26. The probable error of this difference is 42. Since the difference is only 6/10 of the probable error, the chances are only 2 out of 3 that there would be any difference.

A comparison of gains distributed among individuals shows a slight average gain in favor of the test group, the difference being 24.2, but the number of cases is so small and the mean variations are so high that the difference can hardly be regarded as significant. The objections to this method of comparison were discussed in connection with individual gains in substitution.

The average fatigue index for the first week, computed for 16 children in each group, is 1.016 in each group with a m.v. of 0.077 for the test group and 0.12 for the control group. For the second week the test group fatigue index is 1.056, m.v. 15, control group, 1.060, m.v. 13. The difference is only 0.004 and is only 1/10 of its probable error, which is 0.045. Thus the motor results, compared with respect to average amount distributed gains and rate of fatigue, show no more than a chance difference between the two groups.

The results of this study show that the change in ventilation made at the Jackson school produced no appreciable effect upon the work of the children in the tests with the possible exception of a slight difference in substitution work, which may be explained on other grounds. The work of the children in several forms of psycho-physical activity furnishes the basis for this conclusion: (1) solving problems in short division, a task involving a high type of selective thinking and memory processes; (2) learning to make substitutions, a task partly mental and partly motor; (3) movement of the index finger, a strictly motor act. In neither the division nor in the motor tests is there indication of any effect of change in ventilation, and the slight difference observable in the second week's substitution work is not outside the range of chance error. The work was examined with reference to total amount, rate of improvement, and rate of fatigue, and in all these respects, except that cited above, the work of the



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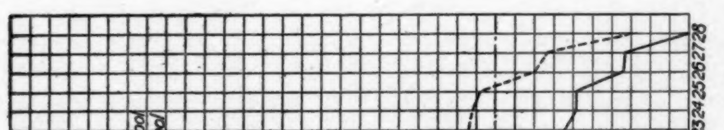

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3. CURVES SHOWING INDIVIDUAL MOTOR GAIN. 4. CURVES SHOWING INDIVIDUAL SUBSTITUTION GAIN.

test group showed practically no variation from that of the control group where the ventilation was unchanged.

CONCLUSION

From the standpoint of the engineer, it is interesting to know that it is possible to renew the air of a fully occupied school room for a period of 3 hr. (with recess period as usual) without the use of outside air other than that which leaked through crevices and occasionally opened doors and other minor openings, and during this period to keep the air sweet and comfortable. It is further interesting to know that the continuation of this form of air renewal day after day, 5 hours each day (3 hours and 2 hours) for three weeks had no perceptible effect upon a group of school children under careful observation by expert observers making physiological and psychological determinations. The conditions in the room were such that the teacher and pupils were perfectly content and satisfied at all times and unaware of the fact that they were not being treated to the air of the street instead of the renewed air of their own room. At one time during the test the small fan supplying ozone went out of commission temporarily and the effect was noticed within 20 to 30 min. by the teacher, who felt that the air was "stuffy," although she had no way of knowing of the accident. Apparently in this case the ozone was an important factor in keeping the air of the room in a comfortable condition. Ozone has an affinity for water vapor, and, if there were enough of it, humidity might be reduced by it, but in this experiment there was not enough ozone to affect the humidity materially. The humidity due to evaporation from the pupils may have been partially removed by condensation on the cold surfaces of the distribution pipes in the basement and by the air leakage from the room.

The psychological tests were evidently very carefully planned and executed; their value for such work cannot be doubted, for their delicacy is admirably fitted to detect and measure the elusive effects which have been usually described as "sense of oppression," "dullness," "restlessness," "sleepiness," and others due to poor ventilation. The work done by Mr. Kitson in analyzing and arranging and correlating his observations indicates a standard of completeness not often reached in tests of ventilation con-

ducted outside of laboratory conditions, but it is work of a character worthy of consideration in the preparation of standard psychological or physiological field tests.

The physiological tests made by Dr. Huenekens were quite complete so far as they went, but circumstances made it impossible to make blood counts or hæmoglobin tests as would have been desirable. There is undoubtedly a large undetermined personal equation in the blood pressure determinations. The temperature observations lead to no valuable conclusions.

The apparatus for the experiment delivered to each child, whether at his seat or at the blackboard, a refreshing current of cool air, with a small quantity of ozone. The humidity was moderate, averaging 32.6 per cent., as was the temperature, averaging 68.8 deg. F. The velocity of the center of air current 2 ft. away from the desk funnel, or at the usual position of the face, was 1½ ft. per second. The oxygen content might have been low and the carbon dioxide content might have been high, but, since so many investigators have conclusively proven that, under such conditions as obtained in this experiment, these were negligible factors, these determinations were not made. There are further desirable data that might have been taken had it been possible; the temperature and humidity of the air in the control group would have been recorded, variations in humidity each day in both groups, actual measurements of air leakage among the physical factors, blood counts, hæmoglobin tests, conditions and environment of pupils outside of school, histories among the physiological data, and more extended physiological tests. A longer period of observation would have been desirable but was impossible under local limitations.

The results show conclusively that in rooms and auditoriums only occasionally used, such as lecture rooms, theaters, churches, not subjected to repeated occupancy by the same persons, the revolving and renewing of air by proper treatment may be as desirable as the use of outside air. It seems probable, too, that persons may occupy rooms ventilated by renewed air for a great length of time, certainly for periods as long as three weeks, without suffering or even exhibiting any effect either consciously or unconsciously. Air leakage will supply more than enough oxygen.

It would seem to me that the time has come when old stand-

ards of ventilation and methods of ventilating practice should be radically altered. More extensive, comprehensive, complete experiments along the lines of this limited work need to be performed, and, as a result of such experiments, a new science and a new practice of ventilation of buildings should be established.

The psychological work of this investigation was done by Mr. H. D. Kitson, M.A., and a large part of the work done and description herein are his. Any success attained has been due to his enthusiasm.

DISCUSSION.

J. W. Shepherd: You have asked my opinion of Prof. Bass's paper, and I will briefly state my impression from a somewhat hasty reading of it.

I fully agree with Prof. Bass that in past practice too much emphasis has been placed merely on the quantity of air for ventilation purposes. I am also sure that many of your Society are of the same opinion; in fact, it is a matter of personal knowledge with me that some of you have had this opinion for the last four or five years, at least.

No doubt, everybody also accords with the belief that the real end of good ventilation is physical and psychical well-being. The end of ventilation is to contribute to the efficiency of people indoors.

I am in full accord with Prof. Bass in his endeavor to furnish an individual supply of air to all the pupils. For nearly three years I have been doing similarly with a school room containing forty seats, a room used by high school students mainly.

Prof. Bass and his co-workers have made a good beginning at adapting standard psychological laboratory tests to a school room of elementary children. There are so many factors involved in a test of this kind that one must approach the conclusion very slowly and cautiously. The short period of time and the relatively small number of pupils used in the reported test, together with the possible mechanical inaccuracies and other factors of control no doubt, account, in part at least, for the lack of assurance in the evidence obtained. The only conclusion I can draw from the report on this phase of his work is that he has made a good beginning, and, if continued, the work may lead to a practical conclusion.

I fear that in some respects I may not agree with Prof. Bass. I infer from the whole paper that he favors a reduction in the quantity of air supplied for ventilation according to our present standards to such an extent that he must depend on an extraordinary oxidizing agent being present in a room in order to prevent an outcry of discomfort by its occupants. My own opinion is that the standard aimed at for the ventilation of all enclosed rooms should be ventilation as we find it outdoors. In other words, we should strive to make outdoor conditions prevail indoors, and I believe that the most profitable source of future investigation will be that in which we seek to determine what the factors are that produce good ventilation outdoors. I suspect that if a group of ventilation students were to make a list of the factors which contribute to the making of outdoor ventilation we should find a lack of unanimity.

By reading the two paragraphs, referring to carbon dioxide as an indicator, one might infer that there are sensory "impurities" which have no other effect than to produce a state of psychological discomfort. As a matter of fact, there are, at present, experiments going on at Harvard which may show that exhaled air is toxic.

From the conclusion the author arrives at it would seem that Prof. Bass favors a recirculation of air within a building, rather than providing for fresh air to come in from outdoors for ventilation purposes. Except for the novelty of such procedure there seems to be no advantage in this plan over that in usual practice, unless it results from its being cheaper to run an ozone machine and air washer than to lose heat from the air which is expelled from a building with the usual ventilation installation. Lest I forget it in this connection let me say that the air washer, in my opinion, is far more important from the standpoint of health in the general problem of ventilation than is the ozone machine. Next in importance to furnishing each individual with an adequate supply of fresh humid air, I believe devices for cleaning the air, for example by washing, follow closely.

Finally may I say that our own personal experience with outdoor ventilation, whether at work or in repose, has always been satisfactory. Moreover, generations and centuries before us have biologically prepared and adapted us to be content, happy, and healthy when furnished with outdoor ventilation.

Mr. Hart: I have not very much to say, only it occurs to me that, in looking over the methods applied, it might have been just as efficient a system of ventilation had Prof. Bass installed several oscillating fans in the room to move the air in the room and put his ozone machine in the room to remove the smell. I do not see why that would not have been a cheaper method of installation and given the same result.

Prof. Hoffman: I rather regard this paper as being a recommendation for the ozonator, and possibly somewhat for the air washer. We read in here that when the ozonator stopped they were called to account almost instantly, and we are told by those who know the ozonator real well that it is a purifier. I won't vouch for that, but we are told that it is. Further than that, we know that ozone is a form of oxygen, and very unstable, and breaks up very quickly, and that the breaking up of oxygen takes away that portion which has been supplied by other forces.

Mr. Lewis: I think this is a recommendation for ventilation by displacement, that is the only conclusion that we are given any assured safety in drawing from it. The question of the psychological tests mentioned in this paper was submitted to a very prominent Chicago psychology expert, who stated that, while these results were no doubt recorded accurately, that without a very long test and without most careful calibration of the instruments used in testing psychological results, no dependence of any great value could be placed upon the result, that it was a matter of such delicacy that it was not safe to draw conclusions from it. The Chicago Ventilation Commission in the Chicago Normal School has had a class of adults under very similar conditions for a long time. The greatest difference between the results obtained in Chicago and the results recorded in this paper seems to lie along the effect of humidity. It was found in Chicago that, by carrying the humidity up to 50 per cent. or 55 per cent., the temperature could be brought down to as low as 63 degrees. with perfect comfort. It seems rather strange that they should have lost sight of the effect of humidity to such an extent that they should have maintained it as low as they did, 32 or 33 per cent. It seems rather strange that in recirculating the air for two or three weeks they should have been able to retain the air at such a low humidity. It seems

that in circulating the air with the warm water they would have saturated the air in a short time. It has been suggested that the only reason they could account for the low humidity, as shown by these tests, was leakage. There is another thing about this paper. To deliver the air to the individual desk of the pupil seems to be all right as long as they are at that desk, but what happens when they are at the blackboard or standing? If they sit at the desks, all right, but if they are not at the seats you are not getting the results.

Mr. Carrier: It would be impossible to use a washer in which the water was maintained warm, as evidently was the case, and hold the humidity down when recirculating the same air. A similar set of tests has been in operation at the Springfield Y. M. C. A., with exactly the same type of washer that was used in this case where they had taken the air from the gymnasium floor, taken it from the washer, and passed it back into the machine, and they got results that were very good; in fact, the occupants of the floor could not tell the difference between the recirculated air and fresh air, as long as the washer was in operation, but the humidity did increase, and it increased when they shut off the heating of the water and recirculated the water without any heat being applied. It would run up to between 60 and 70 per cent., where it got to be very objectionable.

Another thing in this paper—it mentions the fact here that ozone has an affinity for water and, if there is enough of it, the humidity will be reduced. I am very sorry that Prof. Bass is not here, because I would like to ask him about this—how this could be brought about. I put it up to Dr. Franklin—supposed to be an authority—and he says that so far as he knows ozone does not have an affinity for water.

Dr. Hill: This paper opens up so many questions, in reality the whole subject of ventilation, that I hesitate to make any remarks; there are, however, some features in the paper of which I should like to speak. The first is one that I find a great many people, ventilating engineers as well as others, frequently lose sight of, and that is that the analysis of air for carbon dioxide is nothing more or less than a convenient method of determining the fresh air supply. If you stop to think of it (of course you know it but you do not always remember it), the amount

of carbon dioxide in a room where there is no other source of contamination bears a direct relation to the amount of fresh air supplied. When we make analysis for carbon dioxide this is in reality all we have in mind. A quite prevalent impression in the past has been that carbon dioxide in itself is a harmful ingredient of respired air, but physiologists for the past 50 years have realized that carbon dioxide in itself is practically harmless. It is simply an index to the amount of respiratory contamination. In this case before us the author states no CO_2 analyses were made; in other words, he does not know how much air was supplied per pupil; he knows the amount supplied by the mechanical system in use, but does not take into consideration the residual air in the room or the leakage through doors, windows, etc. To make this proposition clear take the case of a frame schoolhouse, a one or two-room affair, such as is frequently encountered in country districts, where three, or possibly four, sides of a room are exposed to the weather and where the windows are not especially tight, with a high wind velocity, a sufficient air change is obtained through leakage to give the pupils sometimes 1,000 cubic feet per person per hour. This would mean a carbon dioxide analysis of 10 parts. I have any number of analyses showing 8, 9 and 10 parts of carbon dioxide in churches where no mechanical system of ventilation is employed and where the fresh air supply is obtained entirely from leakage and from the residual air in the room. This means that each person in the audience is being supplied with from 1,000 to 1,500 cubic feet of air per hour; so from the experiments of Professor Bass we have no means of knowing what was the total amount of air supplied per pupil, what was the construction of this building, how much leakage there was around the doors and windows and what would the carbon dioxide analyses show. To continue observations of this kind I would suggest that another schoolroom of ordinary type and construction, with say three sides exposed to the weather, with the same number of pupils, under like conditions, be carefully watched. The chances are that we would find practically no difference in that short period of time.

As to the ozone proposition, Professor Hoffman, I think it was, spoke of that as a deodorizer. The ozone molecule is so constructed that it very readily gives off an atom of oxygen

which combines with the organic material producing the odor, oxidizing or burning it. No one has, I believe, contended that these odors are especially harmful only, as you might say, in a psychological sense.

The blood test, to my mind, means absolutely nothing. I have made tests of the blood pressure of factory workers under various conditions and they show so wide a range that I could obtain no results of any value, both in ventilated and non-ventilated rooms. My own blood pressure, taken twice, one week apart, gave 128 millimeters in one case and 122 in the other. The variation is so wide under different conditions that I cannot see that it helps us much. There are so many other factors that enter into a test of this kind that experiments extending over three weeks mean practically nothing. Furthermore, the tests do not give us any insight of micro-organisms in the air, whether they are removed or not and what effects the system would have in cases where harmful organisms are present.

Now the American Society of Heating and Ventilating Engineers is a scientific organization and I think that any conclusions reached should be based upon scientific observations only. If you will read the last of this paper you will find the statement, "The results show *conclusively* that in rooms and auditoriums only occasionally used, such as lecture rooms, theaters, churches, not subject to repeated occupancy by the same persons, the revolving and renewing of air by proper treatment are as desirable as the use of outside air. Does this paper or does the data submitted warrant these sweeping conclusions? Personally I cannot say that it does. To determine what the results might be of this method of ventilating schoolrooms would require a careful study to determine the actual amount of air supplied, would include a careful determination of dust, bacteria, and other harmful constituents of the air, and the experiments should extend over a considerable period of time. To say that outside air ducts and indirect heating ducts are entirely unnecessary is a conclusion which the facts in this case do not warrant.

Mr. Weinshank: I am of the same opinion as Dr. Hill, namely, that the tests made brought out a good many points, and especially that the deodorizer destroys organic matter in the air. The question I want to raise is whether this method could be applied to an auditorium requiring about 50,000 or

75,000 cubic feet of air per minute. The question I ask is from a commercial standpoint.

Mr. Lewis: I think the third from the last paragraph will lead to the very greatest harm, and that it would be a great mistake to permit this to be published anywhere as having been presented to the American Society of Heating and Ventilating Engineers, if not most radically condemned. If you eliminate that paragraph there is not much harm in anything that is said. I believe that the nearer we approximate outside conditions the more nearly we arrive at an ideal system of ventilation. We were given a sense of smell to tell us to get away from anything that would be liable to harm us, and that is why, when we get into a roomful of people that has been occupied for a long time, we want to get out as soon as we can.

Mr. Hart: I think that while it is agreed among ventilating engineers that there are no injurious effects in carbon dioxide, I don't believe they are agreed as to what the injurious effects of vitiated air are, and it seems to me that there is a great field for laboratory experiments to discover just what the injurious effects of vitiated air are. It is quite evident that we do not know. But we do know there are injurious effects there just the same, because we can see it by the results. We must not overlook the fact that in these experiments the pupils were not in the room more than one and one-half hours at a time, then they had recess, then they probably went home for lunch. When he says they occupied this room for a period of three weeks, that means possibly six hours per day for three weeks, in periods of one and one-half hours each, with recess between each period. I think we all know that when we are in a condition of air that is uncomfortable and start a fan we feel better anyhow, but at the same time we would not like to stay in such conditions for any length of time, that is, for ten hours a day for our lifetime. And as to the conclusion I agree with what has been said. The conclusions are rather faulty, and I do not think that the paper justifies the conclusions at all. I think that any physician would condemn recommending that any person breathe vitiated air over and over again for a number of hours, because their constitution would undoubtedly in time run down rapidly.

Mr. Lewis: In any building, if the air is to be recirculated,

it will be necessary to provide return air ducts. In a building of any magnitude that would be a very heavy expense, and the operating cost and initial investment would more than offset any saving in fuel.

Mr. Weinshank: Regarding the paragraph, the third from the last, which gives the author's conclusion, I believe that it would be advisable to somewhat change the wording so as to indicate that the conclusions are based only on cases where ozonators are used.

Mr. Lewis: I cannot find any authority indicating that it makes any difference in our senses or in our physical condition whether or not we breathe the same air that we breathed before, or whether we breathe the air that somebody else breathed before. This says "that in rooms and auditoriums only occasionally used, such as lecture rooms, theaters, churches, etc., not subjected to repeated occupancy by the same persons, the revolving and renewing of air by proper treatment are as desirable as the use of outside air." The use of the words "by the same persons" is unfortunate.

Mr. Cooley: In regard to return air ducts, I recollect the experience in Washington when the first buildings for the Bureau of Standards were planned it was desired to maintain constant temperature within the buildings the year round, and a double-duct air supply and single-return air duct system were installed for the purpose of heating and cooling the buildings by the fan blast system. The refrigerating plant was installed, of proper size to remove the quantity of heat that would be radiated from the walls of the buildings, on the assumption that at least 80 per cent. of the air supplied to the room would be brought back to the fan inlet at room temperature. When it was attempted to cool the buildings it was found that the air coming to the fan inlet was at outside instead of room temperature, indicating that they were getting very little if any air from the rooms back to the fan through the return air ducts, but that outside air was being drawn into the return duct system at some point or points.

Mr. Bass: The discussion of the paper submitted seems to have centered about the conclusions, which are generally held to be unwarranted. It is true that in this experiment there was leakage through doors and windows, and perhaps to some ex-

tent directly through the walls. This leakage very likely amounted to as much as two changes of air per hour in the room, but no measurement was made of it, although it was known to be desirable. Much desirable data was not collected, and this fact is mentioned in the paper.

The leakage, however, was probably what might be expected under ordinary conditions and would perhaps average the same, whether the air was being recirculated or being replaced from outside.

The conclusion in regard to the equal desirability of air from the outside and recirculated and renewed air is expressly limited to rooms subject to occupancy for short periods, and further limited to the occupancy of such rooms by different individuals. This last limitation is not, as Mr. Lewis understands, to differentiate between the effect of the expired air of an individual upon himself or upon another, but to eliminate the effect of repeated subjection of any one individual to recirculated air. The conclusion should include a provision to the effect that allowance for average air leakage should be included. In perfectly tight rooms recirculated air would rise in temperature, due to the heat from the bodies of the occupants, and, if the room was as fully occupied as an ordinary schoolroom, the outside temperature would have to be about zero degrees F., in order that the heat lost by radiation from the room would be equal to the heat from the bodies of the occupants. Leakage, however, always occurs, and this was taken for granted in the conclusion.

With a leakage equivalent to one and one-half changes per hour, the heat given off by the occupants will be cared for by radiation and convection losses from a schoolroom when the difference in outside and inside temperatures is about 40 degrees F. When air is recirculated with a less difference of temperature than this, a larger leakage must be allowed for or the air refrigerated; refrigeration would probably be little used under such conditions, but open windows would. The economic advantage of recirculated air is perhaps its greatest recommendation, and this advantage would occur when the difference in temperatures is 40 degrees F. or more. In very mild climates there would be little if any advantage of a system of recirculation.

In view of these conditions which occur, the statement that outside ducts and indirect heating coils are unnecessary should be limited to apply to cold weather conditions where economical operation with satisfactory hygienic conditions is sought.

The ozone necessary to treat 100,000 cubic feet of air would weigh about 3.5 grams, and would take from 0.02 to 0.25 k. w., depending upon the ozonator. This would, with a high class of ozonator and with power at eight cents per k. w. h., cost about $1 per day for the school under consideration. This cost would not be considered prohibitive when it is remembered that the cost of operating such a school house is something like $125 per day.

The statement is made that a three weeks' test means nothing. The writer grants that it is not as satisfactory as a longer test, but he holds that a three-day or a three-hour test would have some value; for instance, in the case of a room occupied by persons for one hour only and not again occupied by them. If any given type of ventilation caused the occupants no discomfort and produced no discernible ill effects, it would be adaptable to those conditions, although not to others where prolonged and repeated subjection to the conditions was made.

In conclusion the writer would say that he believes that not nearly enough study is given to the ventilation of buildings today; there is too much work done of a stereotyped pattern. Each building needs its special conditions studied and a type of ventilating system designed and adapted to those needs.

CCCXXV.

TOPICS FOR DISCUSSION.

VENTILATION AND THE OPEN WINDOW.

M. S. Cooley: The relation of the open window to the science of ventilation, when it is the only means of ventilation provided, and when it is used or misused where other means of ventilation are provided, has formed the subject for many discussions. The writer, having made a few tests bearing directly on this subject, presents his observations so that they may perhaps form the basis for further discussion.

The first case tested was a room comprising approximately 18,000 cu. ft. The height of the ceiling was approximately 26 ft. There were regularly 3 occupants in the room, which was equipped with a window ventilator in the form of a sheet of plate glass set at an angle in the lower part of the frame, directly inside of the sash. When the window was raised there was an opening of approximately 2 sq. ft. area provided for the entrance of fresh air. The carbon dioxide in the air, determined by the Fitz method, with the ventilator closed, was 0.10 per cent.

The window ventilator was then opened, when anemometer readings showed a velocity through the opening of 600 ft. per minute, thus supplying approximately 72,000 cu. ft. of fresh air per hour. This equalled 4 changes of air per hour and 24,000 cu. ft. per occupant. The carbon dioxide in the air after the ventilator had been open for three hours was 0.07 per cent.

Several further tests were made on other rooms with window ventilation, and in no case was a lower percentage of carbon dioxide obtained. In one case with a room of 72,000 cu. ft. contents, having 5 windows 4 ft. wide and 6 ft. high wide open, and having 120 persons, the carbon dioxide was 0.16 per cent.

Another room tested had 6,000 cu. ft. contents and a ceiling height of 13 ft. This room housed regularly one occupant and

was provided with a gravity indirect and a direct radiator. The author found the heat and vent registers closed. Under these conditions the carbon dioxide was 0.10 per cent. Shortly after the author found the room empty. He promptly shut off the direct radiator, opened the fresh-air and vent registers and stayed in the room and smoked. The fresh-air register had a free area of 160 sq. in. and the anemometer showed a velocity through the register of 100 ft. per minute, which gave a fresh-air supply of 6,666 cu. ft. per hour. This gave 1 1-3 changes and 6,666 cu. ft. of air per occupant, and his cigar, per hour. At the end of 35 min. the carbon dioxide was 0.07 per cent., and at the end of 1 hr. the carbon dioxide was 0.05 per cent.

Still another room with approximately 20,000 cu. ft. contents and a ceiling height of 12 ft. was occupied by 18 persons. It was provided with a portable ventilating set, consisting of a fan and heater, which delivered air at about room temperature. The ventilating set was shut down for 3 hr., at the end of which period the carbon dioxide was 0.12 per cent. One hour after starting the fan the carbon dioxide was 0.06 per cent. This system was so well liked by the occupants of the room that difficulty was experienced in keeping it out of service for the period required for making the test. The occupants, however, were all mechanical and electrical engineers.

The results of these tests indicate that air admitted at outside air temperature does not produce anything like as satisfactory results as the introduction of heated air. The explanation in the cases noted is undoubtedly that the cold air falls to the floor, passes across it and finds an outlet near the floor without mixing with the warmer air at or above the breathing line. On the other hand, heated air rises to the ceiling and falls through the air at the breathing line on its way to find an outlet, and appears to be at least three times as effective as the same quantity of cold air.

With relation to the condition in which an open window tends to upset the distribution of heat where a plenum system of heating is in use, the author operated a plant at one time where the window leakage was so great that it was necessary to alter the position of the volume dampers with every change in the direction of the wind in order to heat one of the buildings properly.

In another building there was a room 45 ft. long and 30 ft.

wide, exposed on both sides and one end. This room was provided with one warm-air register in the center of the unexposed end and a vent register about 10 ft. on each side of the warm-air register. It was found that a more uniform distribution of heat could be obtained when the windows on the exposed end of the room, those farthest away from the warm-air and vent registers, were opened slightly. This room was a hospital in connection with an insane institution.

ODD CASE OF ELECTROLYSIS OF PIPING IN BUILDINGS.

THOMAS MORRIN: The writer recently had an experience with electrolytic energy which may prove of interest. All the data he has were taken hurriedly, and as he was caught off his guard, so to speak, by the freak of energy manifestation, he is not prepared at this time to give out any facts which might appear ludicrous when the more thorough investigation which he expects to conduct sometime in the near future has been made.

Many of the members of the Society have undoubtedly had experience with electrolysis in piping systems of buildings where electric street railway lines, isolated and local electric plants, and power and illuminating street systems have caused serious damage to the steam and other piping systems in buildings. Many may have had experiences in which the structural steel has been damaged by this cause, because of the careless grounding or imperfect insulation of electrical distributing mains and wires. The incident which I recently came across, however, is a new freak to me in electrolytic action on a heating system. It was entirely local with the system itself and occurred in one of the well-known vacuum return systems, the design of which includes a separate system of piping for steam supply and for the exhausting of the air through the medium of a vacuum pump or other mechanical contrivance which maintains a more or less negative pressure on the return side.

Serious annoyances were at first caused by the automatic valves refusing to operate. Upon investigation it was found that they were incrusted with a scaly substance built up on the automatic parts, which prevented sensitive and satisfactory action. This substance was highly colored with oxide from what appeared to be common rust or red oxide of iron or steel, indi-

cating a rapid deterioration of the piping system. Recently this action had become so vicious that as much as 1 oz. of oxide was taken from the inside of a standard ½-in. pipe less than 4 ft. long.

On testing for electrolysis we could not find any external interferences whatever, but, on observing by the accidental contact of one of the wires a considerable reading on the electrical instrument, several tests were made by placing the poles of the electrical instrument on either of the two radiator valves when the radiator was cold. When the steam was turned on we found a considerable electric or galvanic current passing through the system. It was found, however, when the radiator and piping had acquired a normal temperature, this electro-thermic condition receded to a mere dip of the needle, as it were.

WHICH, THE SMALL OR THE LARGE FAN, THE HIGH OR THE LOW PRESSURE?

THOMAS MORRIN: Which is the most practicable and efficient method of distributing air for mechanical ventilation: Small volumes at high velocities, and a respectively smaller high-powered fan equipment and duct system, or a larger low-powered fan equipment, with more generous duct sizes for air distribution, space and environment being the same in each case; or, in other words, which is the most economical pressure to work against when interest and depreciation on first cost are figured in connection with maintenance, ½ oz., 1 oz., or 1½ oz.? At present we are all guessing that somewhere in the neighborhood of ¾ to 1½ oz. for motor driven work, and a higher resistance for engine driven, where power is more economical.

The ever-increasing demand for mechanical ventilation coupled with a heating system has given rise to the above question in many instances in the practice of the writer, and has brought out much reasonable and acrimonious criticism and discussion, confined mostly to the results to be obtained, and generally ignoring the conditions as to which is the best investment for the owner and operator when in use for continuous or periodical service.

The volume of air will increase as the square of the difference in the size of the fans, while the power will increase as the cube

of the velocity, showing that if you reduce the size of fan and increase the pressure you will necessarily increase the power required, which increase will be a quantity to be considered during the life of the apparatus.

Should an engineer recommend such conditions when more economical maintenance can be secured with but a small increase in first cost and secure more efficient equipment?

THE BELT OR DIRECT-DRIVEN ELECTRIC FAN.

THOMAS MORRIN: Is the direct-connected electric motor-driven fan unit a step forward from an efficient and engineering point of view when considering the greater extra cost of the electric motor for the speed requirements of the fan when compared with the standard medium or high-speed belted type of motor for the same power, space and environment being the same in each case? The capacity of fans to be not less than 10,000 ft. per min.

The direct-connected fan motor must necessarily conform in speed with the fan requirements to give the most efficient results for the fan service; this requires an extra large motor frame and corresponding electrical arrangement that greatly increases the cost of the motor for the horse-power output, and at the same time a greater armature and field loss of current than is usual with the standard construction for this power.

It has been the writer's experience that where the space will permit, the belted unit is the most efficient in service and first cost, and where all-year service is required it gives a greater flexibility of speed control than is possible with the direct-connected units. Particularly is this true with alternating current for power.

The belted type also often operates with much less vibration or noise than the direct-connected type.

CCCXXVI.

LOSS OF PRESSURE DUE TO ELBOWS IN THE TRANSMISSION OF AIR THROUGH PIPES OR DUCTS.

FRANK L. BUSEY.

Considerable discussion has been presented in the engineering press and before various engineering societies regarding the loss in pressure in heating and ventilating systems due to elbows in the pipe line. It has been shown by different experimenters that the loss through a sharp-turn elbow is the greatest, and that this loss gradually decreases as the radius of curvature of the elbow is increased. It will be the object of the present paper to give the results of a series of experiments carried on at the testing plant of the Buffalo Forge Co. These results will be found to agree more or less closely with results already published by other investigators, but as work has been done along some lines not previously considered, some of the more interesting deductions will be presented herein.

Two sets of experiments have been carried on; the first to determine the effect obtained by changing the radius of curvature of the elbow; the second to study the effect of reducing the throat of the elbow to the theoretical or blast area.

The general arrangement of the apparatus used in making these experiments is shown in Fig. 1. It comprised a blower equipped with an arrangement for varying the air quantity—an air-tight box into which the air is blown—and an outlet from the box so arranged that the different elbows or fittings may be attached and their effect studied. The discharge outlet was fitted with a short length of pipe three diameters long, and a Pitot tube mounted in the center of the pipe one diameter from the outlet. The elbows were attached to the outlet end of this short pipe and another piece of pipe three diameters in length placed on the outlet end of the elbow. For the series of experi-

ments here discussed, the outlet from the box as well as the elbows used were either 12 in. in diameter or of a 12 x 12-in. square section.

In making these experiments the static pressure in the box was accurately measured, and by means of a sensitive differential gauge attached to a Pitot tube in the short outlet pipe the velocity pressure of the air in the outlet was also noted. As different elbows were attached to the outlet pipe the speed of the fan was increased so as to maintain a constant pressure reading at the Pitot tube. The static pressure in the box increased and the increase noted as a measure of the resistance

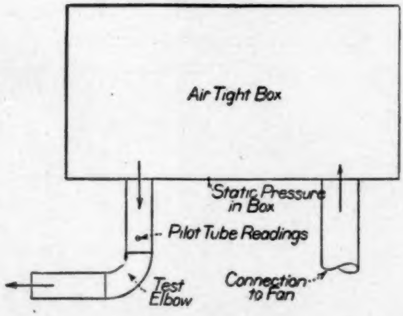


FIG. 1.—GENERAL ARRANGEMENT OF TESTING APPARATUS.

or pressure loss of the elbow used. The same procedure has been employed in measuring the resistance of various outlets and fittings as well as of straight pipe.

Careful tests were made to determine the coefficient of the short length of pipe attached to the outlet of the box, and 0.825 selected. That is, the actual velocity through the pipe or the effective area of the pipe will be only 82.5 per cent. of that indicated. The velocity head producing the discharge will then be the static pressure reading in the box multiplied by the square of 0.825. Any increase in static pressure due to the addition of an elbow to the outlet expressed as a percentage of the velocity head as determined in the foregoing gives a direct measure of the pressure loss due to this especial elbow as a percentage of the velocity head. Quite an extensive series of

experiments were made with various static pressures and rates of discharge.

PRESSURE LOSSES DUE TO ELBOWS.

As has been already explained in a paper presented before this Society,* the losses in the piping system are made up of two parts, the dynamic losses and the friction losses. The dynamic losses are composed of the loss of entrance and the loss in the elbows and connections. Thus we see that one of the two chief sources of dynamic loss is in the elbows, and this loss depends not on the size, or on the velocity of the air, but on the radius of curvature of the elbow.

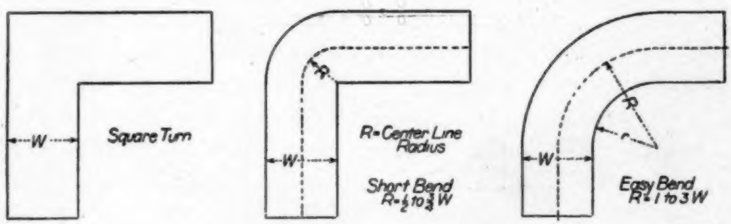


FIG. 2.—TYPE OF ELBOWS USED IN TESTS.

The character of the elbows used in these experiments is shown in Fig. 2. They were either round, 12 in. in diameter, or square, 12 x 12 in. in section, elbows of similar radius of curvature being tested in both the round and square sections. What is here termed a square-turn elbow is shown in Fig. 2 as being actually of a square or two-piece type. While this may not be considered a common type of elbow, it was used to determine what the extreme condition might give. The term short-bend elbows is used to designate those elbows having the outer surface rounded off and the inner angle either square or sprung to a very short radius. This would be the case where the center-line radius varied from one-half to three-quarters of the pipe width or diameter. The easy-bend elbows were those having a center-line radius of from one to three times the pipe width or diameter.

* The Design of Indirect Heating Systems with Respect to Maximum Economy of Maintenance and Operation; American Society of Heating and Ventilating Engineers, 1913, by Mr. Frank L. Busey and Willis H. Carrier.

Nine elbows, each of the round and square section, were used, as follows:

R = Center-Line Radius		r = Throat Radius Inches
In Diameters	In Inches	
Square turn	....	....
0.50	6	0
0.75	9	3
1.00	12	6
1.25	15	9
1.50	18	12
2.00	24	18
2.50	30	24
3.00	36	30

The two accompanying diagrams (Figs. 3 and 4) of pressure loss in elbows, based on actual test results, show respectively the loss by friction through elbows of either round or square section. The loss in per cent. of a velocity head is given for elbows of

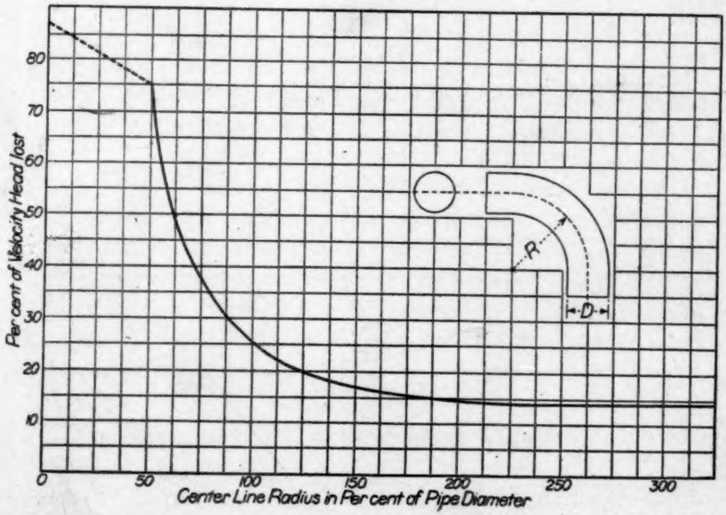


Fig. 3.—Diagram Showing Pressure Loss in Round Elbows.

different radii, the center-line radius being expressed as a percentage of the pipe diameter or width.

It may be seen from these diagrams that with R = 1½ D, or an inside radius of one diameter, fairly good results may be

obtained, without making the elbow unduly long. Practically nothing is gained by making the radius R greater than 2 D.

It is also evident from an inspection of these diagrams that if it can possibly be avoided an elbow with R less than one D should not be used. Even with R = D an elbow in a square duct will cause a loss of 17.5 per cent., and in a round duct 25.5 per cent.

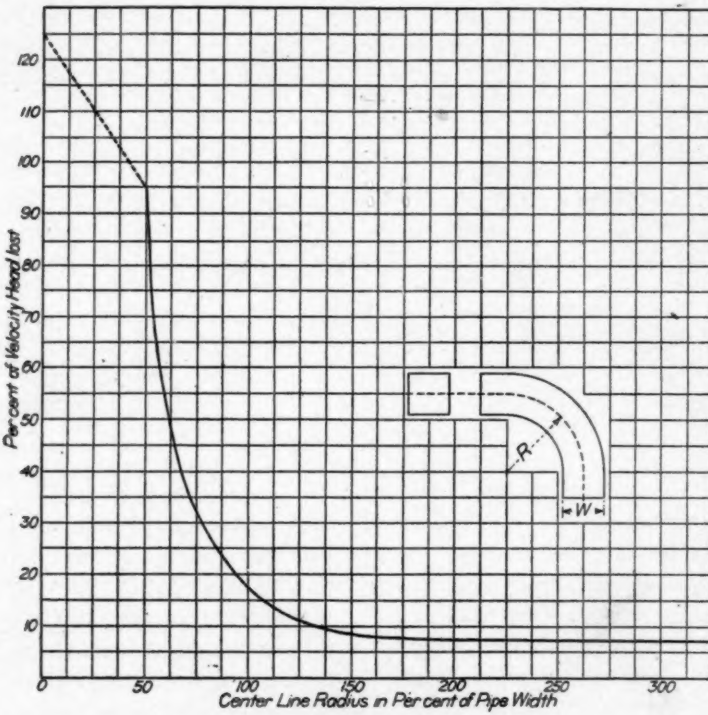


FIG. 4.—DIAGRAM SHOWING PRESSURE LOSS IN SQUARE ELBOWS.

of the velocity head. In case R = ½ D (throat of elbow square but outer side rounded to a radius of one diameter) the loss in a square duct will be approximately one, and in a round duct three-quarters of the velocity head. The loss indicated on the diagram for R = O, represents tests on elbows of two-piece construction, or with both inside and outside made square. It is evident that this construction should never be used, since in

the case of the square pipe 25 per cent. of the loss may be saved by making the outer surface round (R = ½ D).

From the curve for the round ducts it will be seen that with an elbow having R = 1½ D the loss will be 17 per cent. of the velocity head. If we consider one velocity head lost in 50 diameters of straight pipe, this means that this elbow is equivalent in friction effect to 8.5 diameters of pipe. If the elbow were in a square duct the loss would be equal to 4.5 diameters (or widths) of pipe. With a velocity of 2,000 ft. per minute through the duct, corresponding to 0.25-in. pressure, or a velocity head of 0.25 in., the foregoing elbow in the round pipe would cause a loss of 0.0425 in. and in the square ducts of 0.0225 in.

For ordinary calculations one easy long-radius elbow in a circular pipe may be considered as equal in friction loss to 10 diameters of straight pipe. This is the factor used by Mr. N. S. Thompson in his book, "Mechanical Equipment of Federal Buildings," as applied to elbows having a center-line radius of 1½ diameters. Prof. L. A. Harding, in an article on "The Design of Air Ducts," in *The Heating and Ventilating Magazine* for April, 1913, gives one elbow having a center-line radius of R = 1½ D as equal in pressure loss to 10 diameters or widths of pipe. No distinction was made between round or rectangular sections, but according to the tests here considered the loss was not the same for both sections except for a very short-radius elbow having a center-line radius of R = 0.6 to 0.65 D. With elbows having R = 1¼ D, or greater, these tests show the loss for round section elbows to be approximately twice that for elbows of square section.

SPECIAL VENTURI STYLE ELBOWS

A series of tests have also been made in an effort to determine the effect of reducing the area of an elbow at the throat to the theoretical or equivalent area. The shape assumed by such an elbow is shown by Fig. 5. This special form of elbow was suggested by Mr. Konrad Meier in his book, "Mechanics of Heating and Ventilating," and the idea advanced that by reducing the area to the equivalent orifice, eddy-currents would be prevented along the inner side of the pipe. This would tend

to prevent one source of friction, and the long cone effect would aid in changing the accelerated velocity pressure at the turn of the elbow back to static pressure with a minimum loss.

Of the total loss of head in rounding an elbow, about 44 per cent. is regained in the straight part of the elbow after making the turn, and the balance, or 56 per cent., is entirely lost. The loss in pressure due to any elbow, as shown by the diagrams already given, divided by 0.56 gives the total loss at a point just after rounding the turn, or at the point where the theoretical orifice or blast area is to be calculated. By adding 1.0 to this total loss and taking the square root of the reciprocal, we find the theoretical area as a percentage of the actual area.

As an example of this calculation we will assume an elbow in a 12 x 12-in. duct, the elbow to have a center-line radius of

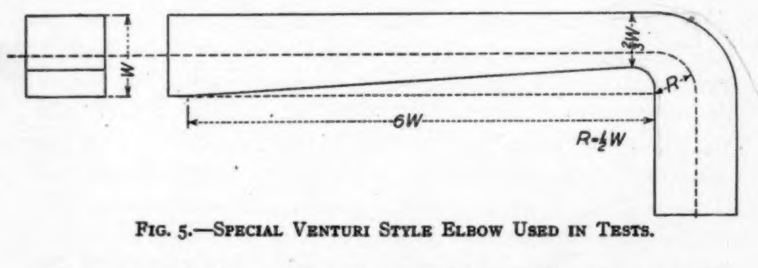


FIG. 5.—SPECIAL VENTURI STYLE ELBOW USED IN TESTS.

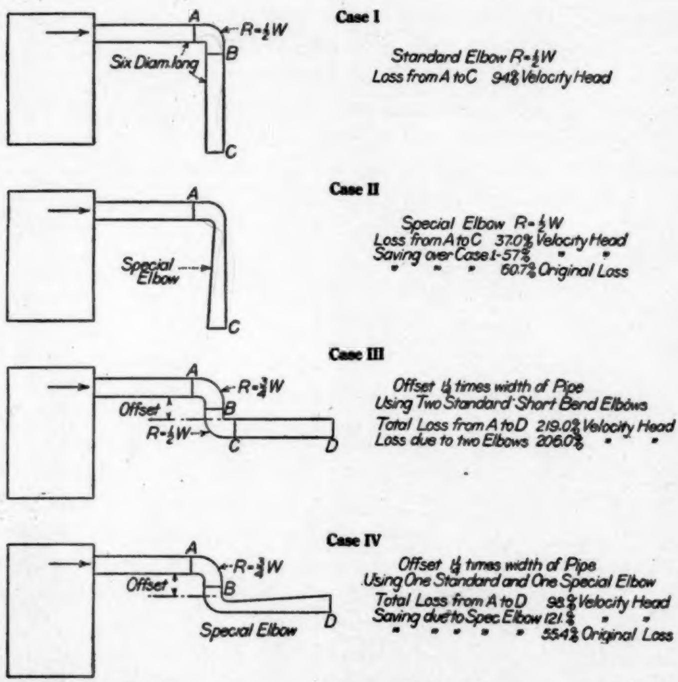
½ W. According to the diagram (Fig. 4) the loss in this elbow will be 0.95 of a velocity head, and the loss at the point of equivalent orifice will be $0.95 \div 0.56 = 1.6$ velocity. Then we will have as the blast area

$$\sqrt{\frac{1}{1.6 + 1.0}} = 0.62 \text{ of the present area.}$$

The foregoing represents an extreme case, and it seems safe to assume that we may say for ordinary square-turn elbows the theoretical area is two-thirds of the actual area. That is, with a 12 x 12-in. elbow the width or area of the pipe may be reduced as shown in the sketch to two-thirds of the normal size without interfering with the air flow or causing an increase in velocity due to the restriction. The greater the center-line radius of the elbow considered, the less will be the loss of pressure through the elbow and the more nearly the theoretical area

will approach to the actual. Thus with an elbow having a center-line radius of 1½ D the theoretical area would be 94 per cent. of the actual.

In order to study the effect of reducing the throat of an elbow as just described, special Venturi shaped elbows were designed on the foregoing basis, and their effect ascertained in the same manner as had been already done in the case of ordinary elbows.



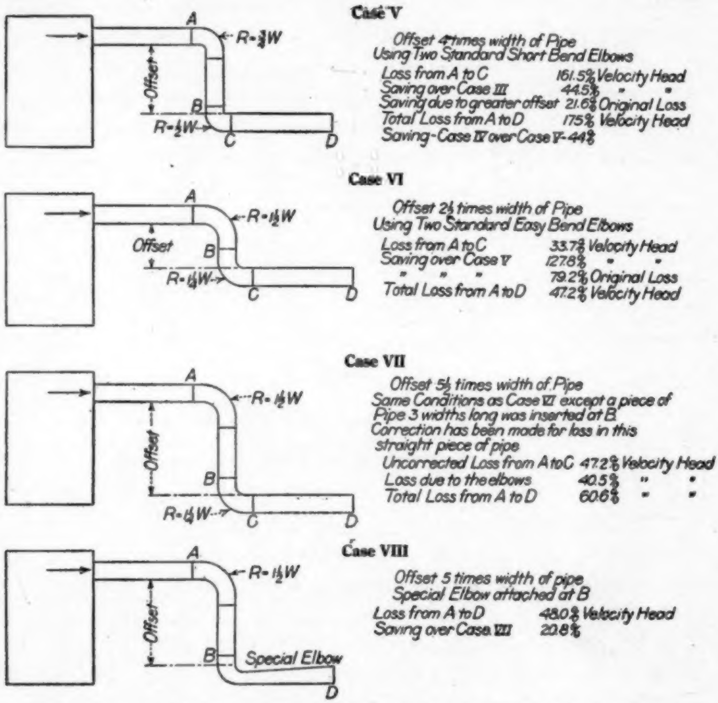
DIAGRAMMATIC EXPLANATION OF SPECIAL ELBOW TESTS AND RESULTS.

The results of these tests are here given, and the accompanying sketches will aid in understanding the arrangements of elbows used.

Case I—A standard elbow having R = ½ W was attached to the outlet of the test box and a 6-ft. length of pipe added to give the same length as used in making the special elbow. As indicated on the sketch the loss due to the elbow and 6 ft. of pipe was 94 per cent. of the velocity head.

Case II—The standard elbow was replaced by the special Venturi-shaped elbow, and the same conditions as to air pressure maintained. The loss now was 37 per cent. of the velocity head, showing a saving of 57 per cent. of a velocity head, or 60.7 per cent. of the loss indicated for the standard elbow.

Case III—An offset of 1¼ times the width of the pipe was arranged and two short-bend standard elbows used. The total



DIAGRAMMATIC EXPLANATION OF SPECIAL ELBOW TESTS AND RESULTS.

loss from A to D was found to be 219 per cent. of the velocity head.

Case IV—The second elbow was replaced at B with the special elbow and the loss found to be 98 per cent. of a velocity head. The saving due to the use of the special elbow is seen to be 121 per cent. of a velocity head, or 55.4 per cent. of the original loss.

Case V—An offset of 4 times the pipe width was arranged

with the two short-bend standard elbows, and the loss from A to C found to be 161.5 per cent. of a velocity head. The saving over Case III due to the greater offset was 21.6 per cent., but the arrangement shown in Case IV, where one special elbow was used, showed a saving over Case V of 44 per cent.

Case VI—Two easy long-radius elbows were arranged as shown, to determine the saving due to these elbows as compared with the ones used in Case V. This arrangement gave a saving of 79.2 per cent. of the loss indicated for Case V.

Case VII—The same elbows were used as in Case VI, and a short length of pipe inserted between the elbows, increasing the offset from 2½ to 5½ times the pipe width. For some unaccountable reasons the loss indicated was greater than for Case VI. It is possible that this arrangement is more productive of eddy currents in the second elbow than the arrangement of Case VI.

Case VIII—The same arrangement as used in Case VII, except the second elbow was replaced with the special elbow. As indicated, a saving of 20.8 per cent. over Case VII was obtained.

APPLICATION OF THE VENTURI STYLE ELBOW.

As may be noted from the data given, the principal gain due to the special elbow is when it is used to replace a short-bend standard elbow in which the loss of pressure is excessive. Special elbows were also tried with a center line radius of 1½ W, but, as might be expected, the gain was not sufficiently great to warrant the extra expense of construction.

This special elbow might be used to advantage in either of two cases. First, where a horizontal run enters a riser at such close quarters that an easy elbow is out of the question and a sharp-bend elbow with center-line radius of ½ W must be used. Second, where a close off-set must be made, as might be required in passing around an obstruction or through a wall. If the off-set is sufficiently great to permit the use of long-radius easy-bend elbows it is questionable whether it would be worth while to use the special elbow. The loss due to the easy standard elbows would be so slight that the saving due to the special elbow would be insignificant.

According to the test results the saving due to the use of the

special elbow, as in Case II, resulted in a saving of 0.57 of a velocity head as compared with a short-bend elbow. When used to replace the second elbow in an offset, as shown in Case IV, the saving was 1.21 of a velocity head. In either event the saving was from 55 to 60 per cent. of the original loss.

DISCUSSION.

Professor Hoffman: I was rather hoping that Mr. Busey might have carried this a little further and tried it upon square piping and square elbows; that is, square in section or rectangular in section, I should say, and then in addition to the long curve they put in what is commonly known as the "splitter" to see what effect the splitter in the air conduit would have in reducing the air pressure. I had considerable experience in running some of those tests myself this winter. I think they were not conclusive at all, but they proved to me that the splitter placed in a rectangular section elbow was a decided advantage in reducing the pressure and increasing the amount of air put through the tube.

CCCXXVII.

CHART FOR DETERMINING SIZE OF PIPE FOR GRAVITY HOT-WATER HEATING SYSTEMS.

M. S. COOLEY.

The calculations involved in accurately determining the proper sizes of piping to be used in a gravity hot-water heating system have formed the subject of at least two papers read before this Society, both of which have given rather complicated formulæ with which to determine the commercial size of piping, the use of which requires a greater expenditure of time than the average engineer can well afford to spend on such a small item in the design of a large or small heating layout. Although several charts for determining the sizes of hot-air and vent piping, and ducts, as well as the sizes of steam piping for both high and low pressure work, in which all the variables involved are easily traced and the results accurately determined by simple operations have been published, the author has not found any similar chart by which the many variables involved in the calculation of a system of piping for hot-water heating can be easily traced and the proper pipe size determined by simple methods. Such a chart was constructed by the author some five or six years ago and has been used by him in the calculation of some rather complicated systems of piping with good results. The method by which it was devised and the manner in which it is used form the subject of this paper.

VARIABLES INVOLVED.

In the calculation of hot-water piping four variables are involved, viz.: temperature drop, or the difference between the temperature of the flow and return water at the radiator when the size of connections to radiators is being determined, and in the flow and return mains when the size of these mains is being

determined; working head, or the vertical length of the warmer and colder columns which produce the flow of water in the pipe; length of pipe, which is a factor in the friction which the force due to the difference in the weight of the warm and cold columns must overcome, and size of pipe, which also affects the friction.

Temperature Drop: This variable affects, first, the quantity of water which must pass through the radiator in order that a given number of heat units may be available in a given time. The greater the temperature drop the smaller the quantity of water that must be passed through the radiator in a given time to liberate the same number of heat units. Second, the difference in weight of the vertical columns producing the flow. The greater the temperature difference the more power is available with a fixed height of vertical columns to produce the flow. Third, the velocity necessary to deliver the required weight of water. The greater the difference the lower is the velocity necessary in a given sized pipe to deliver the required heat units and therefore the lower the friction.

Working Head: This variable affects only the force available to produce the flow. The greater the head the greater is the difference in weight of the vertical columns with the same temperature difference.

Length and Diameter of Pipe: These variables affect the friction which must be overcome by the difference in weight of the vertical columns.

Symbols Used: In the following calculations the symbols used are:

t=temperature difference between flow and return in degrees Fahrenheit.
e=working head in feet.
l=equivalent length of pipe in feet.
d=diameter of pipe in inches.
f=friction in pounds per square inch.
f^1=friction head in feet of water.
v=velocity in pipe in feet per second.
R=radiation in square feet.

Friction: Weisback's formula for loss of head caused by friction of water in pipes is given in Kent's pocket-book as

$$f' = \left(0.0144 + \frac{0.01716}{\sqrt{v}}\right) \quad \frac{l\,v^2}{5.367\,d}$$

$$f = \frac{62.55}{144}\,f' = .43\,f'$$

For values of v usually encountered in gravity heating systems (i. e., 0.1 to 1.5 ft. per second) the following formula gives almost identical results:

$$f = \frac{0.0025\,v^{1.7}\,l}{d} \qquad (1)$$

Available Head: The pressure available to overcome this friction loss is the difference in weight of the vertical columns of water in the flow and return piping.

The difference in weight of a cubic foot of water at the temperatures usually encountered in hot-water heating systems (i. e., 160 deg. to 180 deg. F.) is approximately 0.022 lb. per cubic foot for each degree difference in temperature. Therefore the head available will be

$$f = \frac{0.022\,t\,e}{144} = 0.00015\,t\,e \qquad (2)$$

Equating (1) and (2)

$$0.00015\,t\,e = \frac{0.0025\,v^{1.7}\,l}{d} \quad \text{or} \quad v^{1.7} = 0.06\left(\frac{t\,e\,d}{l}\right) \quad \text{and}$$

$$v = 0.191\left(\frac{t\,e\,d}{l}\right)^{0.6} \qquad (3)$$

Assuming that each square foot of direct hot-water radiation emits 180 B. t. u. per hour, then

Pounds of water per hour required $= \dfrac{180\,\text{R}}{t}$ or $\text{R} = \dfrac{\text{lb. water} \times t}{180}$

The cubic feet of water passing through a pipe d in. in diameter in one hour at a velocity of v ft. per second is

$$\text{Cubic feet per hour} = \frac{3600\,v\,d^2\,0.7854}{144} = 19.635\,v\,d^2$$

and the pounds of water per hour passing through this pipe will be

$$60.55 \times 19.635\,v\,d^2 = 1188.9\,v\,d^2$$

Therefore $\text{R} = 6.6\,v\,t\,d^2$

Substituting the value of v found in equation (3) we have

$$R = 1.261 \frac{t^{1.6}\ e^{0.6}\ d^{2.6}}{l^{0.6}}$$

Here we have an equation for the radiation which can be served by a pipe of a given diameter involving the four variables hereinbefore stated.

In forming the chart a logarithmic scale was employed and each variable eliminated from the equation and represented by a line on the chart, and by using successive lines inclined at an angle of 45 deg. multiplications eliminating one variable at a time were made until the final result was obtained graphically. The first variable eliminated was t, and in performing this elimination closer results were obtained by taking into account the variation in the specific heat of water at different temperatures and the variation in the rate of heat transfer with variation in the average temperature of water in the radiator. The calculations for a 20 deg. drop are given as an example of the method used.

Temperature of water entering radiator is assumed as 180 deg. F., and the rate of transfer of heat from the radiator to the room as 1.8 B. t. u. per degree difference in temperature between the water in the radiator and the surrounding air.

Temperature of entering water 180 deg. F., of leaving water 160 deg. F. Average temperature 170 deg. F.

B. t. u. per square foot (170—70) 1.8=180 B. t. u. per hour.
B. t. u. in 1 lb. of water at 180 deg. F.=148.54
B. t. u. in 1 lb. of water at 160 deg. F.=128.37
B. t. u. available from 1 lb. of water = 20.17

180÷20.17=8.924 lb. of water required per square foot of radiation per hour equals 0.1474 cu. ft.

Area of pipe in square feet $= \frac{d^2 \times 0.7854}{144}$

Velocity in pipe to serve 1 sq. ft. of radiation = cubic feet ÷ area or $v = \frac{0.1474 \times 144}{3600 \times 0.7854\, d^2} = \frac{0.0075}{d^2}$

Weight of 1 cu. ft. of water at 160 deg. = 60.98 lb.
Weight of 1 cu. ft. of water at 180 deg. = 60.55 lb.
Difference 0.43 lb.

Available working head to overcome friction $= \frac{0.43\,e}{144} =$ $0.003\,e$ lb. per square inch, which equals the friction or

$$\frac{0.0025\,v^{1.7}\,l}{d} = 0.003\,e$$

$$v^{1.7} = \frac{0.003\,e\,d}{0.0025\,l} = 1.20\,\frac{d\,e}{l} \quad \text{and} \quad v = 1.11\left(\frac{d\,e}{l}\right)^{0.6}$$

Equating the values of v we have:

$$1.11\left(\frac{d\,e}{l}\right)^{0.6} = \frac{0.0075\,\text{R}}{d^2} \qquad \text{R} = 148.5\,\frac{e^{0.6}\,d^{2.6}}{l^{0.6}}$$

Solving this equation for various values of e the inclined line near the upper right-hand side of the chart marked 20 deg. was determined, and in a like manner the lines marked 10 deg., 15 deg., 25 deg., and 30 deg., were determined. Next the dotted lines inclined at an angle of 45 deg. at the upper left side of the chart were placed in position in proportion to the 0.6 power of the various lengths acting as a multiplier, the horizontal passing through any intersection of a diagonal at the upper right-hand side and a vertical e intersects these latter diagonals on the horizontal eliminating l. Next the solid diagonals at the left-hand side of the chart were placed in position in proportion to the 2.6 power of the actual pipe diameters, and using these again as a multiplier the radiation is read on the left-hand margin.

The foregoing formula gives the elevation e necessary to overcome the friction loss in the pipe. There will be required in addition to this a further elevation sufficient to produce the velocity in the pipe, i.e., to overcome the velocity head, which is represented by the formula $v = \sqrt{2gh}$, h being in feet or the height of a column of water giving the difference of pressure necessary to produce the flow.

As the velocity in any pipe when serving a given amount of radiation is dependent on the drop of temperature within the radiator, this elevation will also be a function of the temperature difference and must be computed for each temperature difference. The calculation for 20 deg. drop is as follows:

Difference in weight of flow and return 0.43 lb. per cubic foot, which gives a pressure of 0.003 lb. per square inch for each foot of elevation, e. The head necessary to produce a pressure of 1

lb. per square inch at a temperature of 180 deg. is 2.375 ft., and the pressure produced by an elevation of 1 ft. with 20 deg. drop is 0.0065 lb. per square inch. Therefore the pressure produced

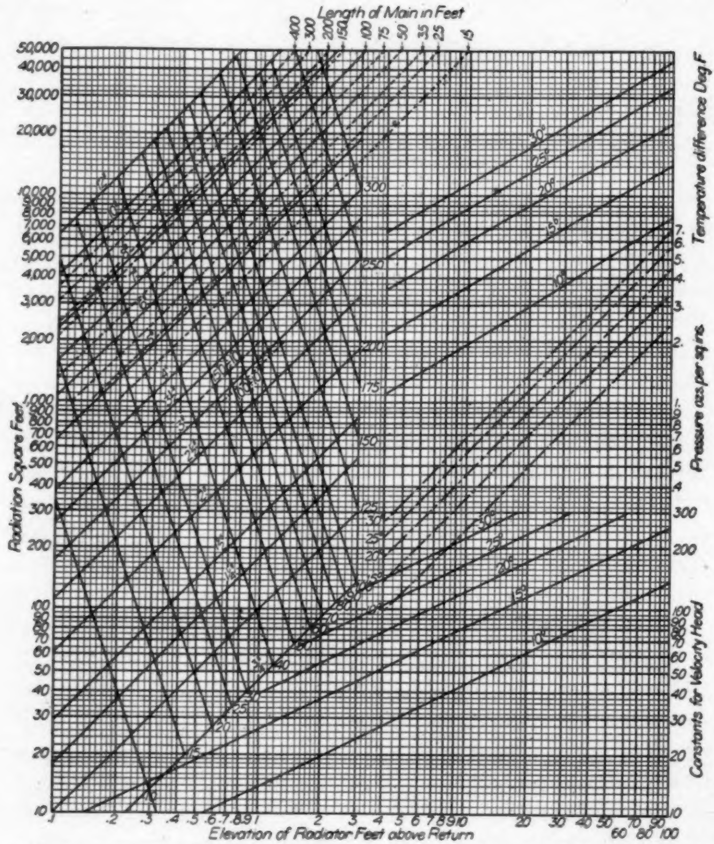


CHART FOR DETERMINING SIZE OF PIPE FOR GRAVITY HOT-WATER HEATING SYSTEMS.

by any elevation, e, is $0.0065\, e = h$. Substituting in the formula $v = \sqrt{2gh}$ we have $v = \sqrt{64.4 \times 0.0065\, e}$, or $e = \dfrac{v^2}{0.418}$ for 20 deg. drop.

The head is determined in the table by noting the diagonal crossing the intersection of the pipe size and radiation lines and

transferring the number on this diagonal to the right-hand margin and following the horizontal opposite said number to its intersection with the diagonal near the bottom of the table representing the temperature drop, and thence vertically from this intersection to the lower margin, where the elevation necessary to produce the velocity head is read.

The diagonal lines near the center of the right-hand side of the table are for reducing the pressure produced by the difference in weight of water in the vertical columns of the flow and return sides of the system to ounces per square inch, and were placed on the chart in order to check its results with a table which was being calculated by Mr. Geo. E. Reid, of the Supervising Architect's office of the Treasury Department in which all friction losses were expressed in ounces per square inch. They are of no particular value in calculations for gravity work, and give too low pressures to be of any value in connection with forced circulation work. The pressure is determined by following the vertical line representing any head to its intersection with the diagonal line near the right center of the table representing the temperature difference and then passing from this intersection horizontally to the right margin where the pressure can be read.

INSTRUCTIONS FOR USE OF FRICTION DIAGRAM IN CALCULATING SIZES OF HOT-WATER HEATING PIPES.

One-Pipe System Main in Basement. Radiator tappings, branches and risers: First ascertain the distance from the bottom of the flow main to the top of the radiator. Find this number at the base of the table and follow vertically to the intersection of the line inclined toward the left near the top of the table corresponding to the difference of temperature desired between flow and return connections to the radiator. Now follow the horizontal line passing nearest to this intersection toward the left until it intersects the dotted line inclined toward the left, and corresponding to length of connections from main to radiator and back plus:

For each long turn elbow or gate valve	5 ft.
For each short turn elbow or angle valve	10 ft.
For each globe valve................	20 ft.

Now follow the vertical line, passing nearest to this intersection to its intersection with the horizontal line opposite the figure in the left-hand margin corresponding to the amount of radiation to be supplied, and the solid diagonal line inclined toward the left that passes above this intersection is the size of pipe required.

Example: Elevation 6 ft.; temperature difference 15 deg.; equivalent length 50 ft.; radiation 100 sq. ft. What size pipe required?

Follow line from "6" at base of table to intersection with diagonal 15 deg. They intersect on horizontal line "2800"; then follow line "2800" to intersection with dotted diagonal "50." They intersect on vertical line "26." Follow this to intersection with horizontal line "100." The solid diagonal inclined toward the left above this intersection is "2 in."; therefore a 2-in. pipe will be required.

We have still to determine the head necessary to produce this velocity. To obtain this find the diagonal line inclined toward the right passing nearest to the intersection of diagonal "2" and horizontal "100." This is "10" or "constant for velocity head." Follow horizontally from the figure in the right margin near the bottom corresponding to this constant to its intersection with the lower diagonal 15 deg., and the head to produce this velocity is found in the lower margin and in this case is 0.14 ft. This must be added to the friction head. In nearly all gravity work this velocity head is so small it may be neglected.

If we wish to know the pressure in ounces per square inch equivalent to this head and temperature difference, follow the horizontal "6" to its intersection with the broken diagonal 15 deg., near the center of the table. Then follow the horizontal line to the right margin, where the pressure in ounces per square inch is found to be 0.2.

To ascertain size of main, use the distance of the flow main at its lowest point to the bottom of the boiler as elevation, and the length of the main from the boiler back to same plus allowance for elbows, valves, etc., as equivalent length. Use a drop greater than that assumed through radiator, and proceed as explained for radiator.

For Two Pipe, Reversed Circulation System. With flow main, in basement, measure total water travel from the boiler to the first story radiator and back to the boiler, plus allowance for fit-

tings as equivalent length. Use the distance from the bottom of the boiler to the top of the first floor radiator as elevation. Ascertain sizes for the first floor. In a like manner ascertain sizes for the second floor, third floor, etc. Now combine these sizes into a single pipe having equal carrying capacity, in the following manner:

Note the figure on the left-hand margin, corresponding with the intersection of the diagonal for each pipe size. Take the sum and note the pipe diagonal, intersecting margin at said sum as size desired.

Example:

2=1 in.; 3=1¼ in.; 1=1½ in. Find pipe of equivalent carrying capacity.

Pipe in.	*Intersection*		*Number*		
1	10	x	2	=	20
1¼	18	x	3	=	54
1½	29	x	1	=	29
					103
2½	110	x	1	=	size required.

This neglects velocity head and is permissible for gravity work only. If the system is not laid out to give equal water travel to each radiator then ascertain the pipe size for each equivalent length and find the pipe of equivalent carrying capacity to the sum of pipes it serves.

Often we have two pipes to equalize, neither of which is fully loaded, and if we equalize as in the foregoing we get too large a pipe. In such cases, and it is better in all cases, to run imaginary lines from the intersection by which pipe size was determined, parallel to the pipe size diagonals to the margin and add the quantities so found to determine the equivalent pipe size.

Example:

Elevation 6 ft.	Elevation 20 ft.
Temp. difference 15 deg.	Temp. difference 15 deg.
Length 50 ft.	Length 75 ft.
Radiation 100 sq. ft.	Radiation 100 sq. ft.
2-in. pipe required.	1½-in. pipe required.

If we combine a 1½-in. and a 2-in. pipe we get $29 + 62 = 91$ $= 2½$-in. pipe.

If we project imaginary diagonals we get $23 + 39 = 62$, or a 2-in. pipe is sufficient.

By noting the intersection of the imaginary diagonal with the margin at each determination, as well as the pipe size, the combining can be quickly and correctly accomplished by addition of these notations.

Overhead System Single Pipe Drops: Use one-half the vertical distance from the flow main to the bottom of the boiler as the head. Make drops the same size for the entire length and large enough to supply the total radiation on such drop. Use temperature difference for system divided by number of stories heated as temperature difference for each radiator in determining size of radiator connections. Use total water travel from the boiler back to same plus allowance for elbows, valves, etc., as equivalent length. If all drops do not have the same water travel determine the size of the main to supply each drop separately and combine, as hereinbefore directed, to determine the size of the main.

Overhead System, with Double Pipe Drops, and Drop Insulated:

Use the distance from the top of the radiator to the bottom of the boiler as the elevation for that radiator, and the total distance from the boiler to the radiator back to the boiler, plus allowance for elbows, etc., as the equivalent length. Ascertain size of pipe for each story separately and combine into pipe of equivalent capacity. If all drops do not have the same water travel determine the size of the main to supply each drop separately and combine to determine the size for the main.

In event the drops or risers in any system are exposed in the rooms there will be a certain amount of cooling in the risers, which is hard to determine. This will tend to aid circulation in an overhead system and retard circulation in a system with flow mains in the basement.

EXPLANATION OF CHART.

Mr. Cooley: The scales on the chart are proportional to the logarithms of the numbers marked on margins, the horizontal

and vertical scales being equal lengths. If a diagonal be placed in this chart running through the intersection of the lines, representing numbers with same digits in vertical and horizontal scales, this diagonal will simply transfer a number from the vertical to the horizontal scale, but, if the diagonal be shifted horizontally, the number in the vertical scale will be multiplied by that number whose logarithm is equal to the horizontal distance the diagonal is shifted and the chart works like a slide rule.

The temperature difference lines are plotted by substituting value of E in the last formula on page 381, giving $R = C \frac{d\,2.6.}{l\,0.6}$ The values of C being taken in the upper right hand margin, with no reference to the decimal point. The dotted diagonals are then placed on the table, same being shifted horizontally the proper distance to divide the constant C by the 0.6 power of the length and the figures on the horizontal scale, then read C^1 where $R = C^1\ d\,2.6$. Another set of diagonals, drawn solid, were then placed on the chart, same being shifted vertically a distance equal to the 2.6 power of the pipe diameter and the radiation is read on the left hand margin.

DISCUSSION.

President Hale: The chart which Mr. Cooley has explained to us is decidedly unique and meritorious, and there is no doubt but that there will be a great deal of comment on it, and a number of questions which the members may wish to ask, and a number of notations which the members may wish to make. You will note on the back of the leaflet there are blank sheets there to make your notations on. The subject is open for discussion, and, as said before, the questions will be asked and the author will make notations of them and answer them all at one time.

Mr. Hart: I would like to ask what factor the professor would use for a 45-degree elbow.

President Hale: Too bad to let this pass without further comment. It represents a great deal of study and labor.

Mr. Hart: I would like to ask another question. I don't know whether it is in order or not, but I have not had a chance

to go over this paper very carefully, and for the purpose of information I would like to know at what point it has been determined the apparatus can be operated most economically, taking into consideration the fuel consumption, the amount of radiation, the size and method of installation of the pipe; that is, at what drop in temperature is it most economical for operation?

Mr. Libby: I would like to ask if I cannot submit some questions by mail to Mr. Cooley?

President Hale: It would be very advantageous to the members if this could be done.

Mr. Cooley: I would be very glad to do that and to turn the correspondence over with a copy of my answers to you.

Mr. Newport: I would like to ask if the formulæ of head loss by friction does not refer to cast-iron pipes, instead of wrought-iron pipe. The friction would be different in wrought iron and cast iron.

Mr. Davis: I would like to ask if all these formulæ are not based upon direct radiation rather than on fan blast conditions.

President Hale: If there are no further questions or comments to be made we will ask Mr. Cooley to answer those that have been asked.

Mr. Cooley: In answer to Mr. Hart, my practice has been to use the same allowance for a 45-degree elbow that I use for the long sweep elbow, and as to the difference of the temperature, which is the most economical, that is something that is rather hard to state. My general rule is, I use 30 degrees generally on a large system, and you can tell better by the way your pipes come out. Of course the lower drop in the temperature you use, the more water will go through the radiator, the larger pipe you will have to have for the same amount of radiation. The way the private residences are piped in Washington, as the steamfitter pipes them up, they will work on a 10-degree drop. My own residence works on that very satisfactorily. I had thermometers on the pipe. It shows about a 10-degree drop, according to the formula here, and that is what it actually works out. It may need a very large pipe on large installation. I have 300 feet of radiation in the house, and we have a 2½ or 2-inch leading off the boiler. The whole thing would go on

a 30-degree drop about on a 2-inch pipe, which would be about what we would use on a large job.

In reply to Mr. Newport's question I believe that formula is for cast iron. There is no guarantee how well the steamfitter is going to ream his pipe; and, considering what the fitter will do to your pipe, it is none too high for wrought iron.

In reply to Mr. Davis, it is figured on 180 B. t. u. per square foot of radiation, and, as I stated before, if the radiation gives anything other than 180, more or less, it is to be reduced by dividing the total B. t. u. required by 100 degrees, and using the quotient instead of actual radiation in the left-hand margin of the table.

Secretary Scott: Before passing to the next point I might explain that Mr. Cooley's paper was the first to come to the Secretary's office and was the last to reach the meeting room. This paper has not been distributed to the members, but will be sent out shortly. I have not asked Mr. Cooley's permission to make this offer to the members, but he has been very good in responding to any requests that I have made of him at any time, so if the members want to ask any questions I will see that they are passed on to Mr. Cooley, and I think he will answer any questions through the Secretary's office. My idea is that we can then embody these questions and answers in the discussion of the paper as printed in the Proceedings.

Mr. Cooley: In that case, Mr. President, would you want me to make an individual answer to each member, or send them through the Secretary's office?

Prof. Hoffman: I feel that this paper is one of considerable importance, and should be so regarded by our Society. I want to state my appreciation of it. I have not had the paper in my hand excepting just a few moments, and do not know enough about it to ask questions. But, just glancing through it, it seems to me to be concise, logical and very simply put.

Mr. Davis: Inasmuch as the members did not receive the professor's paper before we came here, I would like to ask if the Secretary intends to send this paper to the members.

Secretary Scott: The members will get a copy of this paper; if there is anything else to go to the members we will probably mail a copy to them next week.

Mr. Newport: I would like to ask if it will be possible for the Society to reproduce this chart on a larger scale for distribution among the members, so that it can be used?

Secretary Scott: Yes; that can be done very readily. I have a tracing of it now. I had one made.

CCCXXVIII.

HEAT TRANSMISSION WITH PIPE COILS AND CAST-IRON HEATERS UNDER FAN BLAST CONDITIONS.

L. C. SOULE.

The theory of convection of heat with forced circulation of air over indirect heaters has been presented to this Society in a comprehensive manner on two or three different occasions. Theodore Weinshank read a paper before this Society at the summer meeting at Niagara Falls in July, 1908, on the subject of Cast-Iron Heaters for Hot-Blast Work. The tests referred to in his paper were conducted by Prof. J. H. Kinealy. The laws and formulæ governing and establishing the theory of convection were set forth by the author in a paper entitled Cast-Iron Hot Blast Heaters—New Methods in Testing and a New Mathematical Formula Used in Plotting Charts and in Figuring Results. This paper was read before the Society at its semi-anual meeting in St. Louis in July, 1910. A similar mathematical deduction, establishing the laws and constants pertaining to this theory, was presented in a paper entitled Air Conditioning Apparatus by W. H. Carrier and Frank L. Busey at the December, 1911, meeting of the American Society of Mechanical Engineers, and Frank L. Busey in a paper entitled Heat Transmission with Indirect Radiation, read before our Society at the 1912 annual meeting, elaborated on these laws and showed their applicability to the various forms of indirect surface in common use. Mr. Busey showed in his paper that his mathematical deductions, applied to a thorough series of tests on pipe coils, gave results which agreed uniformly with those obtained by the author on a thorough series of tests on cast-iron blast heaters, which results by the author were made universal and comprehensive by incorporating them in a mathematical formula described in his paper and deduced by L. A. Cherry of Vanderbilt University. It is remarkable to

note the uniform agreement of these two sets of test results, when one considers that the two methods of applying mathematically the theory of convection to the test results were entirely different.

Mr. Busey found, in comparing the heating effect of 1-in. pipe coils on 2⅝-in. centers of pipes with Vento cast-iron hot blast heaters, regular sections on 5-in. centers, that for the same friction effect there is practically no difference in the rate of transmission, also that the film resistance to the transmission of heat is the same for all surfaces regardless of their form, but that portion of the transmission resistance which is dependent on the velocity is inversely proportional to the effective velocity and will not be alike for any two designs of heaters. In general, it may be stated that when the velocities in different types of heaters are so modified as to obtain the same frictional resistance the rate of heat transmission will be the same. At equal velocities the rate of heat transmission and the frictional resistance to the passage of air will be different in pipe coils from what these values will be in Vento heaters. Equal velocities of air through two different types of blast heaters have no significance and are unfair to one type or the other. The "effective" velocity, which means frictional resistance to the passage of the air, is the important value to consider.

When an engineer designs a fan system of heating and ventilating he figures the size and speed of his fan to deliver the required volume of air at a definite maintained velocity against a definite continuously maintained resistance which he has previously determined. This resistance is made up of friction of air in the distributing piping and ducts and friction through the blast heater, air washer, inlet ducts, etc. The allowable frictional loss throughout the system should be determined from the standpoint of operating economy. These resistances govern the velocities of the air through the ducts, heater, air washer, etc. In public building work the velocities of air in ducts and through outlets are limited by conditions of noise and draft, and air washer velocities are limited by the manufacturers, so as to insure efficiency of dust removal. The engineer then has determined the maximum frictional loss he can allow in the blast heater. This will mean a lower velocity of air through pipe coils than through Vento heaters. His problem is to heat a given volume of air

through the same range of temperature with a definite allowable friction loss in the heater. Under these "like conditions" he will require the same amount of heating surface whether it be Vento heaters or pipe coils.

This paper will describe a series of 14 tests made at the Institute of Thermal Research of the American Radiator Co., Buffalo, January, 1913, on pipe coils of a standard make, with the 1-in. pipe spaced on 2¾-in. centers. Tests were made on 5 sections,

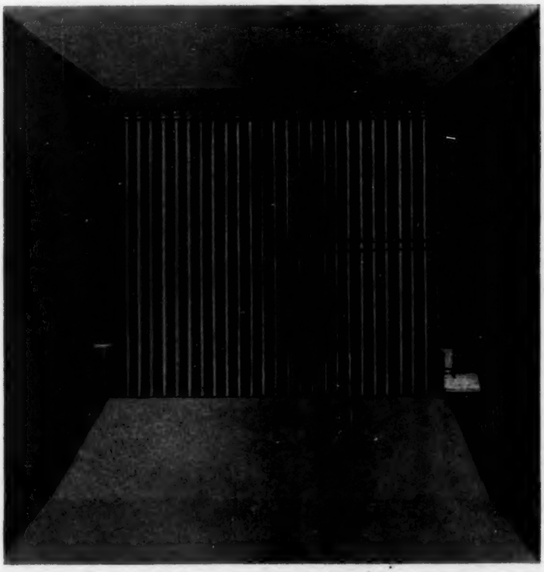


FIG. 1.—FACE VIEW OF PIPE COILS IN TESTING CHAMBER.

3 sections and 1 section deep. Each section contained 4 staggered rows of pipe, making 193.1 sq. ft. of surface to each section, with a clear area for the passage of air of 17.06 sq. ft.

A face view of the pipe coils setting in the testing chamber is shown by Fig. 1. The sides and top of casing fit close up to the coils, leaving the regulation small air space all around. This view shows also the cold-air thermometers protected from radiant heat from the coils, and the static pressure tube on the fresh air side. There is another static pressure tube similarly located on the hot air side of the coils. These tubes and the

gauge showing the frictional loss through the heater are illustrated by Fig. 2. An inclined platform about 4 ft. long extended from the top of the coil base on the cold-air side down to the floor of testing chamber to eliminate eddy currents.

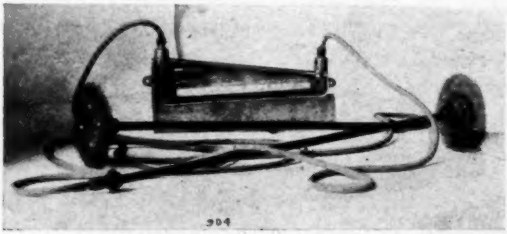


FIG. 2.—STATIC PRESSURE TUBES AND GAUGE FOR MEASURING FRICTIONAL LOSS THROUGH HEATER.

Fig. 3 shows the fan which drew the air through the coils and the variable speed motor for driving the fan.

Steam was generated in cast-iron sectional boilers at pressures

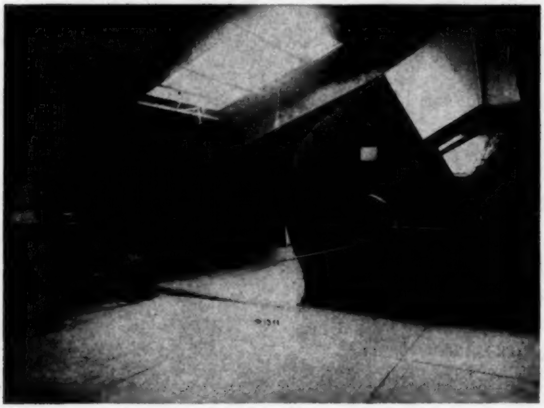


FIG. 3.—FAN USED IN TEST AND MOTOR.

ranging from 9 to 18 lb. per sq. in. These pressures were reduced at the coils to low pressure ranging from 2 to 6 lb. per sq. in. The condensation was cooled and weighed in barrels. There was a steam separator in the high pressure line and a similar

one in the low pressure line. Each coil was vented out of the return compartment on the same end of the coil where steam, return and bleeder connections were made. Each coil had individual valves on every connection. The bleeder header was looped into the return header. A steam jacketed tank, with pressure equalized from the return header, served as a means of observing and regulating the flow of condensation out of the return pipe. The tests were started and stopped with the water level in the tank at a certain height, as shown by a string on the gauge

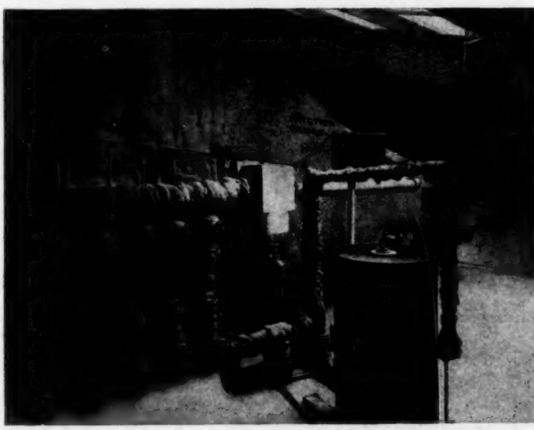


FIG. 4.—VIEW SHOWING VALVED CONNECTIONS TO COILS AND OTHER DETAILS.

glass, so as to keep the bleeder loop sealed but leave the return header dry. The temperature of the steam was taken by a single calibrated thermometer and there was a similar thermometer on the return connection to each coil. These features are illustrated by Figs. 4 and 5.

Before starting a test the coils were found to be hot all over. The variable speed motor and dampers in the discharge piping provided means to obtain any desired velocity of air through the coils. Velocities were measured with a Pitot tube and manometer, and these velocities agreed within an average of 6.65 per cent. with the velocities calculated from the amounts of condensation weighed. The velocities derived from the condensation values were used as test results since these results gave the total

amount of heat taken out of the steam and therefore the maximum heating of the air. The velocities measured with the Pitot tube were lower than those calculated from the condensation, since some heat was radiated out of doors from the face of the coils and a small amount of heat was radiated through the heater casing and through the sheet steel connections between the heater and the fan inlet, although all this sheet steel work was covered with 2 in. thick of hair felt. All the steam, return and bleeder headers and connections were also covered with hair felt.

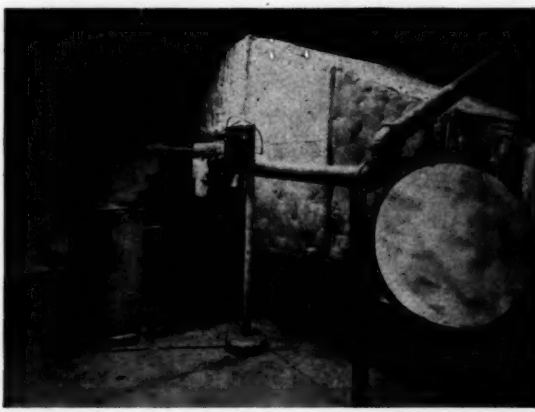


FIG. 5.—VIEW SHOWING TESTING DEVICES AND CONNECTIONS.

The Pitot tube and manometer used were the most accurate type made in this country. It has been calibrated accurately. The velocity tube reads 1.62 per cent. low, as compared with the Thomas electric meter. The static tube reads 3.5 per cent. high, as compared with the piezometer ring. With this Pitot tube readings were taken at *A*, Fig. 6, on one horizontal, one vertical and two diagonal diameters, 10 readings on each diameter, thus making readings at 40 different points. These 40 readings were taken twice in an hour. The average velocity was calculated from these velocity pressure readings and this velocity was reduced to its value for dry air at 70 deg. temperature and 29.92 in. barometer, which is used as a standard. The circular cardboard shown in Fig. 5 marks the points inside the 36-in. diameter pipe

at which the tip of the Pitot tube was set to obtain the various readings. The board at the right side of Fig. 4 shows the location of the pin and block on the outside of the Pitot tube to set the tip of the tube in the desired positions. Fig. 6 shows at D the location of the cold-air thermometers, at E the two static pressure tubes, at C the five thermometers measuring the final temperature of the air and at B the manometer registering the velocity pressure. The location of the friction gauge is shown by Fig. 4. The entire sheet steel work from the cold-air inlet to

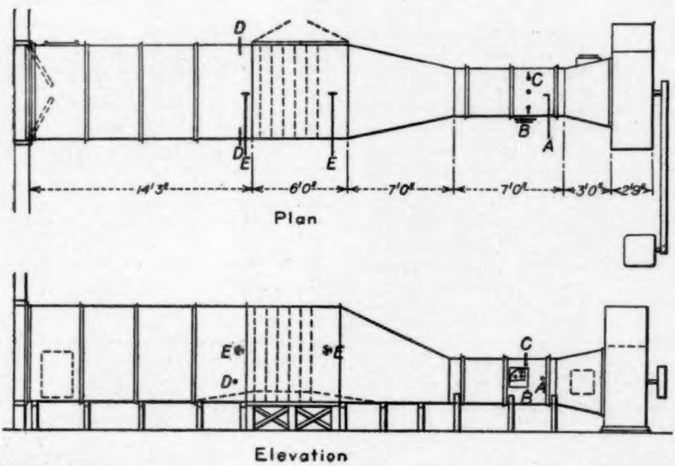


FIG. 6.—PLAN AND ELEVATION SHOWING LOCATION OF TESTING APPARATUS.

the fan was made airtight, since the air was measured on the suction side of the fan.

Tables 1, 2 and 3 show the results of these pipe coil tests and the equivalent values in Vento heaters. The Vento charts have been used to work out the universal performance of the pipe coils. To illustrate, we will take the results from Test No. 5 (see Table 1) on five 4-row sections of pipe coils. Weather clear. Barometer 29.95 in. Temperature of steam in coils 223 deg.

Refer to Vento friction chart, Fig. 7. Draw a horizontal line through a friction of 0.44 in. of water, which is the friction observed in Test No. 5 (see Table 1) for 5 sections deep of pipe coils at 1,054 ft. per minute velocity. This line intersects 3

TABLE 1.—COMPARISON OF 1-IN. PIPE COILS WITH 60-IN. REGULAR SECTION VENTO—5 SECTIONS DEEP—20 PIPES

HEATER	Pipe coils	Vento	Pipe coils	Vento	Pipe coils	Vento	Pipe coils	Vento	Pipe coils	Vento	Pipe coils	Vento
Date of test, 1913	Jan. 8	....	Jan. 8	....	Jan. 9	....	Jan. 9	....	Jan. 9	....	Jan. 9	....
Number of test	3	....	4	....	5	....	6	....	7	....	8	....
Number of stacks or sections deep	5	4.038	5	4.121	5	4.055	5	4.022	5	4.038	5	4.036
Number of loops or pipes wide	25	14.37	25	14.25	25	14.65	25	14.88	25	14.15	25	14.24
Centers of loops or pipes, in.	2.75	5	2.75	5	2.75	5	2.75	5	2.75	5	2.75	5
Friction, in. of water	0.095	0.095	0.31	0.31	0.44	0.44	0.384	0.384	0.25	0.25	0.186	0.186
Velocity of air, ft. per min. at 70 deg.	484	670	860	1200	1054	1430	1000	1335	772	1084	662	925
Free area, square feet	17.06	12.32	17.06	12.22	17.06	12.57	17.06	12.78	17.06	12.15	17.06	12.21
Temperature entering air, degrees F.	23.6	23.6	22.25	22.25	22.2	22.2	24.88	24.88	27.6	27.6	28.4	28.4
Temperature leaving air, degrees F.	128.2	128.2	110.4	110.4	104.4	104.4	108.	108.	117.3	117.3	121.4	121.4
Temperature rise, degrees F.	104.6	104.6	88.15	88.15	82.2	82.2	83.12	83.12	89.7	89.7	93.	93.
Total condensation, pounds	961.5	961.5	1431.	1431.	1639.	1639.	1576.	1576.	1312.	13.12	1169.	1169.
Condensation per square foot per hour, pounds	0.996	1.035	1.482	1.526	1.697	1.725	1.632	1.647	1.359	1.436	1.21	1.27
Per cent. greater velocity with Vento	....	38.5	....	39.5	....	35.7	....	33.5	....	40.5	....	40.
Total heating surface, square feet	965.5	928.	965.5	938.	965.5	950.	965.5	957.	965.5	914.	965.5	920.
Per cent. surface required	100.	96.1	100.	97.1	100.	98.4	100.	99.1	100.	94.7	100.	95.3

TABLE 2.—COMPARISON OF 1-IN. PIPE COILS WITH 60-IN. REGULAR SECTION VENTO—PIPE COILS, 3 SECTIONS DEEP—12 PIPES

HEATER	Pipe coils	Vento	Pipe coils	Vento	Pipe coils	Vento	Pipe coils	Vento	Pipe coils	Vento
Date of test, 1913	Jan. 16	....	Jan. 16	....	Jan. 16	....	Jan. 16	....	Jan. 17	....
Number of test	12	....	13	....	14	....	15	....	16	....
Number of stacks or sections deep	3	2.395	3	2.417	3	2.439	3	2.593	3	2.483
Number of loops or pipes wide	25	14.56	25	14.47	25	14.98	25	14.12	25	14.59
Centers of loops or pipes, inches	2.75	5	2.75	5	2.75	5	2.75	5	27.5	5
Friction, inches of water	0.095	0.095	0.2075	0.2075	0.30	0.30	0.141	0.141	0.241	0.241
Velocity of air, feet per minute at 70 degrees	615	840	917	1260	1130	1500	703	990	987	1345
Free area, square feet	17.06	12.5	17.06	12.42	17.06	12.86	17.06	12.12	17.06	12.52
Temperature entering air, degrees F.	43.5	43.5	43.3	43.3	45.8	45.8	46.9	46.9	51.8	51.8
Temperature leaving air, degrees F.	104.3	104.3	96.3	96.3	94.4	94.4	106.6	106.6	100.8	100.8
Temperature rise, degrees F.	60.8	60.8	53.	53.	48.6	48.6	59.7	59.7	49	49
Total condensation, pounds	711	711	922	922	1042	1042	796	796	918	918
Condensation per square foot per hour, pounds	1.228	1.274	1.592	1.65	1.8	1.788	1.375	1.358	1.586	1.583
Per cent. greater velocity with Vento	....	36.6	....	37.5	....	32.7	....	40.9	....	36.2
Total heating surface, square feet	579.3	558	579.3	559	579.3	583	579.3	586	579.3	580
Per cent. surface required	100	96.5	100	96.5	100	100.6	100	101.15	100	100.12

stacks deep of regular Vento sections on 5-in. centers at 1,645 ft. velocity, 4 stacks deep at 1,440 ft. velocity and 5 stacks deep at 1,297 ft. velocity.

Now refer to Vento temperature chart, Fig. 8. The temperature of the steam in the heater, Test No. 5 (see Table 1), is 223 deg. Subtracting from this the 22.2 deg. temperature of entering air leaves 200.8 deg. Subtracting from 223 deg. the 104.4 deg. temperature of air leaving heater leaves 118.6 deg. Draw these

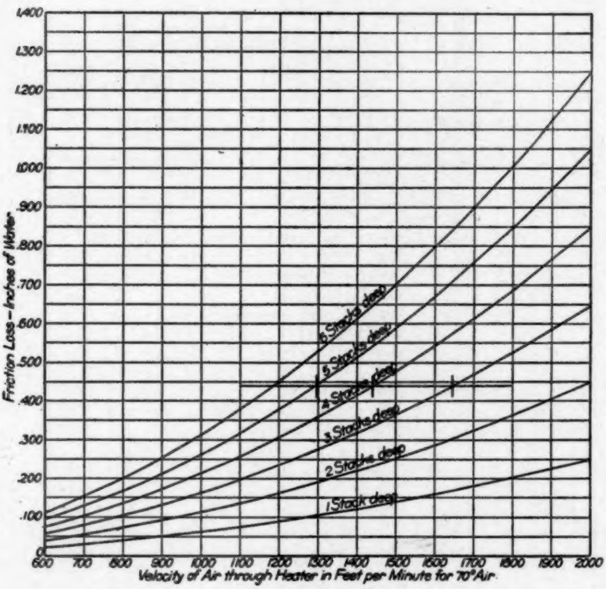


FIG. 7.—CHART SHOWING FRICTION LOSSES.

horizontal lines of 200.8 deg. and 118.6 deg. temperature on the Vento temperature chart. At the points where the 200.8 deg. line intersects 1,645, 1,440 and 1,297 ft. velocity, lay off from these points to the right, 3 deep, 4 deep and 5 deep, respectively, of Vento stacks of regular sections on 5-in. centers. From these new points extend vertical lines upward—each to its point of respective velocity. This gives three points which must be connected with a curve as shown. At the point where this curve intersects the 118.6 deg. line we find a velocity of 1,430 ft. per

minute. Extend a line downward from this point and another line downward from the point of intersection of 1,430 ft. velocity with the 200.8-deg. temperature line and we find the horizontal

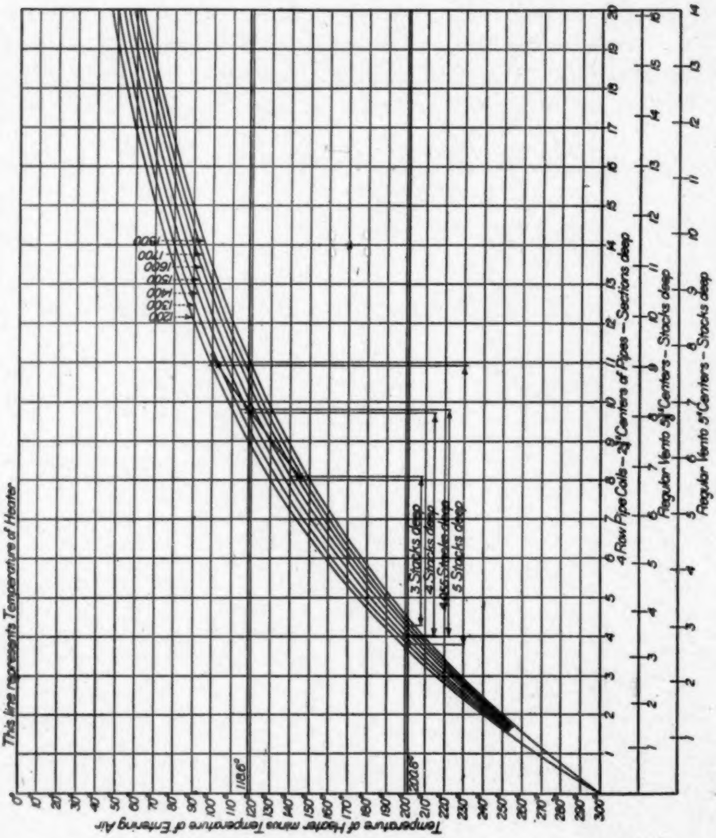


FIG. 8.—TEMPERATURE CHART.

NOTE: The figures on the curves are the equivalent velocities (in ft. per min.) of the air through the free area of the heater, if the air is measured at 70 deg. F., Barometer at 29.97 in dry air.

distance apart of these two vertical lines to be equal to 4.055 stacks deep of Vento regular sections on 5-in. centers. This value for Vento is shown in Table 1 in the column just to the right of pipe coil Test No. 5 with which the Vento is compared.

Test No. 5 velocity through pipe coils of 1,054 ft. per minute,

multiplied by 17.06 (sq. ft. free area), gives air volume at 70 deg., and this volume divided by 1,430 (feet per minute equivalent velocity through Vento) gives a free area of 12.57 sq. ft. This free area is obtained in 14.65 loops wide of 60-in. Vento on

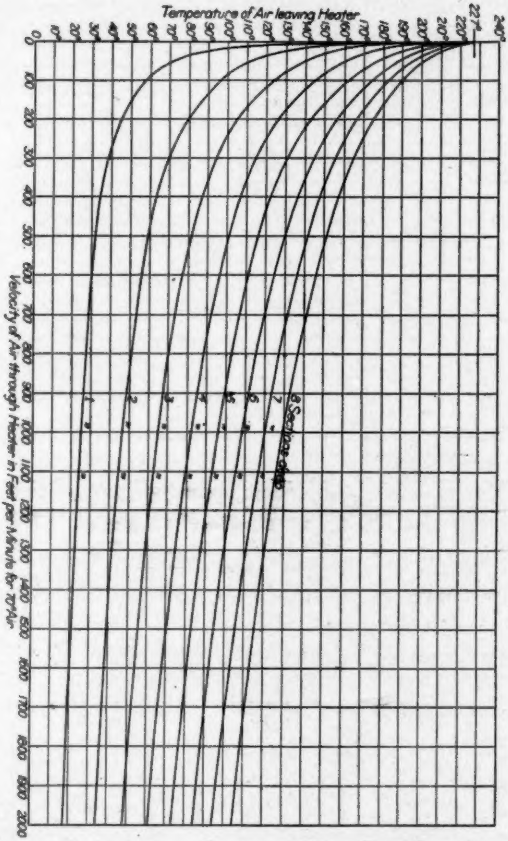


Fig. 9.—Temperature Chart for Four-Row Pipe Coils.
Pipes on 2¾-in. centers—steam pressure 5 lb. by gauge—227 deg. F. air entering at zero.

5-in. centers of loops. From this data we get a total surface of Vento of 950 sq. ft., as compared with 965.5 sq. ft. of pipe coils to do the same work.

Three of the tests indicated about 1 per cent. more Vento required than pipe coils, while in the other eleven tests the slight advantage was in favor of Vento.

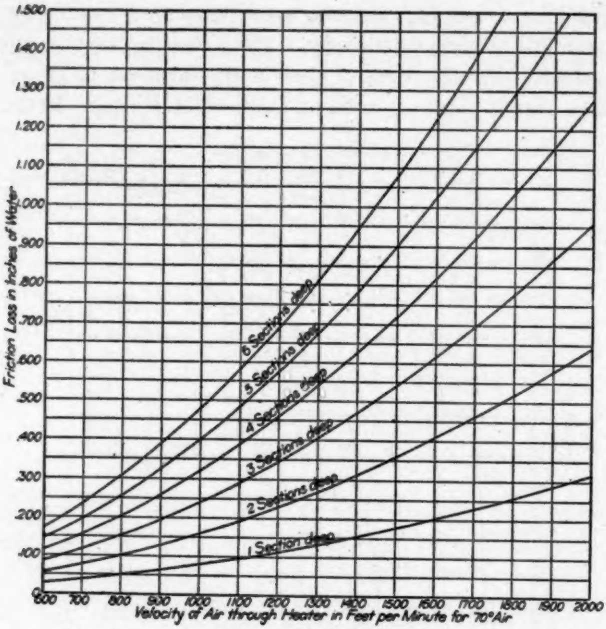


FIG. 10.—FRICTION CHART TO ACCOMPANY FIG. 9.

By plotting all of the pipe coil test results on the universal temperature chart, Fig. 8, we find them agreeing very closely and we have shown at the bottom of the temperature chart a divided line, showing number of sections deep of 4-row, 1-in.

TABLE 3.—COMPARISON OF 1-IN. PIPE COILS WITH 60-IN. REGULAR SECTION VENTO

PIPE COILS 1 SECTION DEEP, 4 PIPES

HEATER	Pipe coils	Vento	Pipe coils	Vento	Pipe coils	Vento
Date of test, 1913	Jan. 14		Jan. 14		Jan. 14	
No. of test	9	....	10	....	11	....
No. of stacks or sections deep	1	0.713	1	0.735	1	0.747
No. of loops or pipes wide	25	16.1	25	15.15	25	14.16
Centers of loops or pipes, in	2.75	5	2.75	5	2.75	5
Friction, in. of water	0.114	0.114	0.0325	0.0325	0.075	0.075
Velocity of air, ft. per min. at 70 deg.	1296	1600	637	835	922	1295
Free area, sq. ft	17.06	13.83	17.06	13.0	17.06	12.15
Temperature entering air, deg. F	30.4	30.4	33.6	33.6	36.75	36.75
Temperature leaving air, deg. F	48.3	48.3	56.7	56.7	56.56	56.56
Temperature rise, deg. F	17.9	17.9	23.1	23.1	19.81	19.81
Total condensation, lb	440.5	440.5	279.5	279.5	347.	347.
Cond. per sq. ft. per hour, lb	2.28	2.394	1.448	1.57	1.796	2.054
Per cent. greater velocity with Vento	....	23.5	....	31.0	....	40.5
Total heating surface, sq. ft	193.1	184.	193.1	178.	193.1	169.
Per cent. surface required	100	95.2	100	92	100	87.5

pipe coils with pipes spaced on 2¾-in. centers. From this chart we can read off the performance of these pipe coils under any usual condition of steam pressure, entering air temperature, number of sections deep and velocity of air through the coils.

To make a simple illustration we offer Fig. 9, which is a chart showing final temperatures from zero for a number of 4-row sections deep, at various velocities of air, and with steam at 5 lb. pressure per square inch in the coils. A friction chart applying to these pipe coils is shown by Fig. 10.

These results show that former temperature charts published for pipe coils having 2¾-in. centers of pipes read much too high and are, therefore, unsafe to use. These results agree with both the Vento tests and Buffalo Forge Co. tests and by their consistency show their entire reliability.

In conclusion, we find from our tests, in comparing pipe coils (with pipes on 2¾-in. centers) with Vento heaters, that for the same friction we have 35 per cent. greater velocity through Vento than through pipe coils—when using one stack deep of regular Vento on 5⅜-in. centers of loops against each section deep of 4-row pipe coils. Similarly, 4 stacks deep of regular Vento on 5-in. centers equal in friction effect 5 sections deep of 4-row pipe coils when the velocity is 35 per cent. greater through the Vento. The foregoing comparisons in this paragraph apply to a condition of raising a given volume of air through the same range of temperature with the same frictional loss. Under these conditions of equality the amount of heating surface required will be the same with pipe coils as with Vento heaters.

DISCUSSION.

Prof. Allen: I would like to call to your attention that in Table 1, Table 2 and Table 3 the total condensation in pounds for the pipe coils and the Vento is exactly the same to the fraction of a pound. I would like to ask if that was obtained by actual experiment, or whether that is a calculated result, and whether the result has been modified by calculation? In making up these charts the actual points of the experiment are not shown. I should like to ask how closely the points of the actual experiments check with the curves on the chart; that is, if the various tests show any very great variation in quantity. The

information given, I want to say, is very interesting, and ought to be of great value in the development of fan work in connection with pipe coils and vento radiation.

Dr. Hill: I would like to ask what that conclusion means—that with the same friction loss the same temperature rise is obtained. It seems rather remarkable to me that that is so, and I would like to ask Mr. Soule why that is so, if he knows; that applies to all types of indirect heaters.

Mr. Brightman: As a visitor to the Society, and as a man who has had a good deal to do with fan heating work, I would like to ask the author if a test has ever been made. Before I ask the question, however, I will say that I noticed the connections to the heaters, both on the return and the supply, were connected into one main supply, which, of course, is absolutely necessary, and the returns were all connected together to stop short-circuiting of the steam in the return lines. The question that I would like to ask is this: Have there ever been any tests made on devices with each section headed to prevent the steam going back into another section upon the return? It seems to me that there might be a good deal of information obtained by arranging the discharge from the heater in such manner that each section will do its proportionate part of the work and, when the condensation of the heaters has been taken and weighed, it would show the amount of work done by each section, where the stacks are four or five sections deep. The reason I am interested to know this is because where there have been four or five sections connected up similarly and trapped under one return, the water in condensation, due perhaps to faulty piping and two or three other things, two or three sections would become heated with steam and the others would fill up with water, and that, of course, would mean that we were not getting the benefit from all the heating apparatus used.

Mr. McCann: I would like to ask the author if he has any data, or if he can put the data into shape for use in addition to this paper as to the friction through various types of pipe coils and radiators in order to obtain the equalization of friction.

Dr. Hill: I find on the market now a good many pressed steel radiators. They are beginning to use them somewhat in blast work. I would like to know whether there has been any information obtained as to the efficiency of this type of heater.

Mr. Still: I think the presentation of this paper was instigated largely because of some of the discussions and arguments between Mr. Soule and myself, time after time, regarding variations in the relative amounts of heating surfaces, whether Vento or pipe coils were specified.

Of course we were dependent upon the data the manufacturer furnished us in arriving at the amount of Vento required; we knew from years of experience what pipe coils would do. It was this state of affairs which led to further tests and investigations by him, culminating in this new theory or discovery that the rate of transmission from different kinds of indirect radiating surfaces, is alike for the same amount of frictional resistance to the air passing over them.

This discovery, if it may be called such, has been made within the past year or two; we have not attempted to prove or disprove it by demonstration, because when it was brought to our attention it was too late to complete the erection of equipment to make experiments, but we now have the apparatus in place in our Experimental Department, ready for a test this coming winter.

The general tone of this paper indicates that the data used by certain of the blower manufacturers is wholly unreliable. One fact remains, however, which is, that we are still building the same type of heater that we have been building for the past eighteen years, and proportioning it from the same data as at first. Mr. Soule was at one time associated with us, having charge of the Heating & Ventilating Engineering Department. While he was in charge of that work I do not think he ever had occasion to question the reliability of the data he had to work with, nor our ability to accomplish results therein specified.

To me there are a good many things which will make it awkward to adapt this newer idea to every day commercial propositions.

When determining the amount of heating surface required, you first have to determine the heat losses to the exposed surfaces to the building and losses from the ducts, etc.; next, the final or maximum temperature at the heater, from which the volume of air to be handled is determined.

Now we have our data arranged so as to show that, with a

given initial air temperature, steam pressure, and air velocity over the heating surfaces, varying final temperatures can be obtained, depending upon the number of sections the air has to pass through. The element of friction has never heretofore entered into the heater calculations, as it has always been, and to my mind should still remain, an element of the fan calculations.

Probably 90 per cent. of the specifications drawn up by consulting engineers state what the maximum allowable air velocity through the coils shall be, thus precluding the possibility of increasing it in some cases so as to equalize the friction.

These same specifications usually state how many sections deep, or how many rows of pipe deep, the coils shall be, or perhaps state what the final temperature shall be.

Again, such specifications not infrequently state what the minimum heating surface shall be.

With any two of the above conditions laid down, coupled with the limitations on width and height so frequently prevailing in public buildings, I can see a vast amount of trouble ahead in trying to equalize the amount of heating surface by frictional resistance.

It will at least be necessary to start an extensive campaign of education, and, as you all know, there are always those who will not be convinced.

Where no specifications are prepared, as usually is the case with industrial plants, we use our own judgment.

Friction cuts no figure with the purchaser in such cases. It is first cost, up-keep, and guaranteed results he is after.

As the final temperature at the discharge end of the coils is the important point of attainment, to obtain which requires a fixed number of sections in depth, when supplied with steam at a given pressure and a predetermined air velocity, and owing to the greater amount of heating surface obtainable with pipe coils per section of depth, with a given superficial area for air passage, it has been our invariable experience that it is possible to use much less surface with pipe coils than with Vento.

I promised Mr. Soule to look into this question carefully some three or four months ago, but pressure of other matters prevented, and his paper did not arrive soon enough to permit looking up some of the jobs about which we have had discus-

sions in the past, for the purpose of checking up with this new theory for presentation at this meeting.

One thing I would suggest as very necessary to make this new scheme operative, would be to prepare new tables, based on friction and also to prepare comparative pipe coil tables based on the tests Mr. Soule has made, so that engineers can readily see just what the relative differences are and what the relative velocities, temperatures, etc., will be. Then a better understanding will prevail, and we can all form our opinions as to whether or not pipe coils or Vento are better suited to the specific case before us.

Whether or not our tests, which we expect to make this coming winter, confirm or disprove the results obtained by Mr. Soule, we will be very glad to make them public through the channels of this Society, if so desired, at a later date.

Mr. Donnelly: I think that pipe coils have usually done better in the past with higher pressure of steam; I think their efficiency increased, due to lack of cold spaces, where there was poor air removal or poor water removal. I agree with Mr. Brightman. I think if the returns of each section of the pipe coil were taken off separately, that the total condensation would be greater than it is at present and it would be much more valuable data. We would like to have it both on the pipe coil and on the Vento. The whole trend of this paper is gratifying, that the manufacturers of two different things can come here and, I believe, submit it to an impartial tribunal without quarreling. It is a very great step in advance. Of course, we know that the Vacuum System people cannot do it. They have not been in existence long enough, youthful and untried, fiery-tempered, they need to do a little more snarling back and forth. Still there is hope for them. Many of them are getting fairly well along in years. Their blood is cooling down and they don't need so much tabasco sauce, etc.

President Hale: A little levity now and then is a great deal appreciated.

Mr. Weinshank: It is my understanding that Mr. Soule's paper is a strictly scientific one, giving us valuable data. Mr. Soule has given us results of a series of experiments. Mr. Soule has also taken us to the plant to show us the apparatus, and the method of conducting the tests. If we have any criti-

cism to make of facts given us, that is what we are here for, but I do regret that Mr. Still has touched the commercial part of the question.

Mr. Soule: Regarding Prof. Allen's question, Tables 1, 2 and 3 show values for total condensation exactly the same for pipe coils and Vento. The values for condensation are exactly as found on the pipe coil tests conducted last January, and, in order to compare the pipe coils with the Vento coils, it is necessary to make the condensation exactly equal, to make the weight of the air passing through the coils exactly equal, and to make the friction equal and then compare the surface. We have four variable quantities in a blast heater, those four mentioned. The best way to compare them, in my opinion, is to make the weight of air, friction and range of temperature the same and then compare the surface. This was the way we handled it. The results shown for the Vento were taken from our universal temperature and friction charts.

The second question was, "How do the points of actual test show on the chart?" That is illustrated by Figure 8. This shows only one test. You will notice on this chart and also by referring to Test No. 5, Table 1, that the entering air temperature is 22.2 degrees; on that particular test the temperature of the steam in the heater was 223 degrees. The difference between 223 and 22.2 is 200.8. That is the difference between the steam and the entering air. That is shown by the horizontal line on Figure No. 8. That is drawn across there to intersect the velocity lines. In the same way 118.6 degrees represent the difference between the temperature of the steam in the heater and the final temperature of the air. Those two points represent the actual test results. Now, to determine how that applies to the actual test, we find where those two horizontal lines intersect the 1,054 feet velocity through the pipe coils. Marking those two points and drawing vertical lines down we get the horizontal distance, which means the distance of hot surface over which the air passes. Taking that horizontal distance, and dividing it up into five equal parts, representing the five sections of four-row pipe coils, we get the length of each section of pipe coil. That happens to be equal to an inch on our chart, the average of an inch from our fourteen tests, and

the sections of coils are plotted off on the first bottom horizontal line on this figure, No. 8.

Dr. Hill asked what is meant by the frictional loss being the same for a given temperature range, etc. That is partly answered by the reply to the previous question, but I might say that, while this comparison of temperature range, surface, frictional loss, and air weight happens to apply to commercial pipe coils and Vento cast iron heaters, it does not necessarily apply to every form of heating surface which might be used with a fan behind it. We have found several different types of blast heaters, some of which have so much wide-open space that this comparison does not apply at all. The efficiency for a given amount of friction will fall way down below Vento values or pipe coil values. In other heaters we have found it to run way up ahead of either, especially on high velocity, due to different construction, closer spacing, different proportions, etc. But on these commercial heaters which we have, the cast iron and wrought iron, this comparison holds.

Mr. Weinshank asks if this 35 per cent. greater velocity through the Vento means the same free area as through the coils. It does not mean the same free area. It means the same weight of air or the same volume at 70 degrees or any other temperature. The free area will vary.

Mr. Brightman asks about running tests on these coils with individual returns from each coil. We have not made experiments of this sort, but they have been made both by the Buffalo Forge Company and by the University of Michigan, where they have individual returns and weighing apparatus for each coil. Our tests, however, check up the results of the Buffalo Forge Company, and, as far as our test apparatus is concerned, I believe there would be very little difference if the returns were connected up separately. It might be desirable to try it out some time. I know that on installations trouble is sometimes experienced, due to all the returns being connected together into a dry return, and that this trouble has been corrected by making a water seal for each return or by putting a trap on each return.

Mr. McCann asked if we have data on the friction through various makes of pipe coils. We have determined the data for the 2¾-inch centers, and we believe that the Buffalo Forge Company has given us very reliable data on the 2⅝-inch cen-

ters, and some other manufacturers publish data on friction through their coils. We believe that the friction data published by the American Blower Company is nearly correct for their coils. On our tests we found the friction about 10 per cent. higher than they show, but it is possible that we ran our tests in weather which was a little warmer than they had when they ran their tests. We had an average outside temperature of 20 or 25 degrees. The same weight of air would have a greater volume if the tests were run in warmer weather than if they were run in cooler weather, and the friction would be greater for a given weight of air, represented by equivalent volume at 70 degrees.

Dr. Hill asks about data on pressed steel radiators for blast work. We understand that some of these radiators are about to come on the market, but we believe that these people who are manufacturing them have not as yet obtained any data. We have tried out one of these radiators, but we have not had enough of the radiators to set up, one behind the other, to get reliable data, so we are not prepared to give any information.

Mr. Still refers to the use of Vento in commercial sizes. We are handicapped to a certain extent by having only three different sizes of Vento, and we cannot give the engineer oftentimes the exact height which he has figured for his pipe coils. We have not as yet gotten out a section which is six feet in height. This always makes it difficult for us to furnish a commercial heater of this sort. We must either furnish one double-deck 40-inch, making 7 feet high, or else the wide heater, 5 feet high. We are getting out a 72-inch section which, if it tests out all right, will be put on the market very shortly. This will help out in making more exact the comparisons with sizes of Vento and pipe coils.

The illustration which Mr. Still made of the Nova Scotia job is very interesting, and shows why it is not fair to compare cast iron and wrought iron blast coils on the basis of velocity. The friction is not the same at all and therefore the comparison is unfair to one or the other.

Mr. Donnelly makes reference to the returns from each section. This is partly answered by the reply to Mr. Brightman's question. I think Mr. Still might give us something interesting

on the matter of individual returns from the pipe coils. He knows more about it than I do.

President Hale: We have a few moments' time, and if Mr. Still wishes to make remarks on that subject we will be glad to hear from him, although the reply is not obligatory on his part.

Mr. Still: I have nothing definite here. I think that is a matter of record. We have made some records on that. For instance in running a test we have three sections along the room, and we have run to one, two, three, all independent. But the fact of the matter is we have never gone after it as an individual section. Prof. Allen ought to be able to tell us something about that, since I believe they have them set up at the University of Michigan.

Prof. Allen: I have been away so long that I have forgotten the results that we obtained, but I would be glad to quote them at another time.

CCCXXIX.

VENTILATING DIVISION OF THE HEALTH DEPARTMENT, CHICAGO, ILL.

DR. E. VERNON HILL.

Mr. President, in corresponding with the Secretary of our society some time ago he thought it desirable that I should present to the society at this meeting an outline of the work we are doing in Chicago, with regard to the enforcement of the ventilation ordinances, with the idea that this would be of value to other municipalities who are undertaking the same kind of work.

In organizing the Ventilation Division of the Chicago Health Department there were two principal objects which we sought to attain. The first was to so arrange our card records, filing devices and inspection work that the most could be accomplished with the small force available and that the methods adopted would be accurate and efficient as a working system.

The second object was to adopt such a system for recording inspections and laboratory tests that a careful analysis of the same at future periods would assist in solving perplexing problems of ventilation work, it being my firm conviction that the importance of the research work of this and similar organizations is second only to that of enforcing the ordinances.

The work of the division embraces the enforcement of ordinances covering the ventilation of street cars, theatres and other places of amusement, department stores, factories, workshops, churches and schools. As it would be too much to attempt to describe the work as applied to all of these various branches, I shall confine my talk to theatre ventilation alone.

I will discuss first the method adopted for the routine work of the bureau as it takes up theatre ventilation and then take up the analysis of the still somewhat meagre data collected during the past winter.

It was early pointed out by Mr. Ball, Chief of the Bureau of

Sanitation, that the first important move was to stop the construction of buildings not adequately ventilated. This in itself would correct a large percentage of the difficulties. The first step, therefore, was to devise a system of plan examining, recording and filing embodying the following essential features:

1. Sec. 880 of the Revised Municipal Code: The plans of every building must be approved and stamped by the ventilating inspector in charge before building permit is issued.

2. The plans must be filed in such a way as to be readily accessible for reference until the building is completed.

3. The record of each plan must be kept and the building inspected from time to time during erection, and the inspections recorded to see that the essential features of the approved plan are carried out.

We were exceptionally fortunate when undertaking this work that the ordinances covering ventilation incorporated in the Revised Building Code of the City of Chicago, passed December 10, 1910, are specific and complete. These ordinances as they apply to theatre ventilation I will briefly summarize:

(a) "Before proceeding with the erection, enlargement, alteration, repair or removal of any building or structure in the city a permit shall first be obtained by the owner, or his agent, from the Commissioner of Buildings.

(b) "All plans and drawings for the construction or alteration of any building or other structure for which building permits are required shall, before such permits are issued, be presented to the Commissioner of Health for examination and approval as to the proposed plan for the ventilation of rooms, light and air shafts, windows, ventilation of water closets, drainage and plumbing."

In the same chapter and article, Sec. 231:

"Plans, Essentials of—All such plans and drawings shall be drawn to a scale of not less than one-eighth inch to a foot on paper or cloth in ink or by some process that will not fade or obliterate; all distances and dimensions shall be accurately figured and drawings made explicit and complete. Each set of plans shall be approved by the Commissioner of Buildings before a permit will be granted. No permit shall be granted or plan approved unless such plans are signed and sealed by a licensed architect, as provided in an Act to provide for the

licensing of architects and regulating the practice of architecture as a profession in the State of Illinois, approved June 3, 1897."

Sec. 232:

"It shall be unlawful to erase, alter or modify any lines, figures or coloring contained upon said drawings when stamped by the Commissioner of Buildings or filed with him for reference. If during the progress or the execution of such work it is desired to deviate in any manner affecting the construction or other essentials of the building from the terms of the application or drawing, notice of such intention to alter or deviate shall be given to the Commissioner of Buildings and his written consent shall be obtained before such alteration or deviation may be made. But alterations in buildings which do not involve any change in their structural members or in their stories, elevators, fire escapes or other means of ingress or egress, or in lighting or ventilation, and that are not in violation of any of the provisions of this chapter may be made without the permission of the Commissioner of Buildings."

Article 26, Sec. 725, is as follows:

"No license shall be issued to any person, firm or corporation to produce, present, conduct, operate or offer for gain or profit any theatrical shows or amusements until the Commissioner of Buildings, the Commissioner of Health, the Fire Marshal and the City Electrician shall have certified in writing that the room or place where it is proposed to produce, present, conduct, operate or offer such theatrical shows or amusements complies in every respect with the ordinances of the City of Chicago."

Article 7, Sec. 371:

"The Commissioner of Buildings, Commissioner of Health, Fire Marshal, City Electrician and the Superintendent of Police, or any one of them, shall have the power, and it shall be their joint and several duties to order any building used wholly or in part for the purposes of Class 4 closed where it is discovered that there is any violation of any of the provisions of this chapter, and keep the same closed until such provisions are complied with."

These ordinances, as you will observe, cover in detail the method of applying for permits to build, the manner in which the plans shall be drawn and filed and attach a penalty for altera-

STREET NO. 5960-62 W Lake St VENTILATION PLAN APPROVED NOV 27 1912

CLASS 1VC USE Theater STORIES 1 (NUMBER) ✓ (CELLAR) — (BSMT.) ✓ (NEW BLDG.) — (ALTERATION) — (ADDITION)

SEATING CAPACITY 586 FLOOR AREA ACCOMMODATES

OWNER H F & G Mulligan REGISTERS 30-14"X16" Floor

ADDRESS 4055 W Madison St. OUTLETS 6-30" vents Roof

ARCHITECT W C Miller LICENSE APPLICATION APPROVED JUN 18 1913

ADDRESS 204 N 41st St. RENEWED

ENGINEER Truitt Plan No. 52030 Book, file. ✓

ADDRESS

SYSTEM OF HEATING AND VENTILATION Plenum Floor introduction

INTAKES 4' X 1'4" Roof

FAN #7 Ilg

MAIN DUCT 3-30X24 to 16X12

BRANCHES as above

Fig. 1.

tions of any character involving changes in structure which affect methods of ingress or egress, ventilation, etc.

The ordinances also provide that before a license to operate any place of amusement be obtained the application for such license must be approved by the Commissioner of Health.

The ordinances further provide that it shall not only be the power but the duty of the Commissioner of Health to close any theatre which does not comply with the provisions of this chapter as to ventilation.

It remained for us, therefore, to devise a system of examining and recording plans and to follow up the construction of the building with careful and repeated inspections.

The first illustration, Figure 1, which I wish to show you is what we call the ventilation plan record. On the face of this card you will note space is provided at the top for the location of the premises and the date on which the plan was approved. Following down the card there is, in addition to the name and address of the owner, architect, engineer, etc., an outline of the essential features of the plan as to size of the fan, size and location of main duct with its branches, the number and size of registers, etc. The last notation is the plan number and whether it is to be found in the book or file. The plans, after they have been stamped as approved by the plan examiner, are folded flat and the number of the premises and the number of the plan written plainly on the upper folding edge. These are filed numerically in a flat file in such a manner that by referring to this number on the record card and looking for the corresponding number of the file it is an easy matter to locate the original plan on short notice.

Figure 2 is the reverse of this card. It is arranged for a reinspection record. The observations noted are made by the inspector after returning from his field work. The first notation on this particular card under date of February 10 is "Under Construction and Walls Being Built," and signed by the inspector. The next inspection was made on May 3 and reads: "Installation of ventilating system nearly completed; three distributing ducts are 24 x 16 instead of 24 x 30 as shown on the plans; eight 24″ globe vents instead of six 30″ as shown on the plans," and signed by the inspector. This was brought to my attention, and as the reduction in the size of these ducts

REINSPECTION RECORD

DATE	CONDITIONS	RECOMMENDATIONS	INSPECTOR
2/10-13	Under construction,	Walls being built	H Diebold.
5/3/13	Installation of ventilating system nearly completed 3 distributing ducts 16"x24" instead of 24"x30" as shown on plans. 8-24" Globe roof vents instead of 6-30"	"	Beckwith
5/5/13	-Letter to Com. of Bldgs. requesting that work be stopped on this theatre owing to the fact that ventilating equipment is not being installed in accordance with plans on file.		
5/8-13	Letter signed by Wm C. Miller arch. that work will be torn out & installed as per approved plans.	Remove stop order	E.V.H.
5/17/13	Alteration nearly completed, work being done according to plans O.K. by Dr Hill		Beckwith
5/28/13	Alterations O.K. No motor		Beckwith
6/10/13	Installation completed	Recommend license	Beckwith.
6/13-13	Work completed,	Recommend license, after seats are set, so number of cubic feet, air supply can be determined.	Diebold.

FIG. 2.

would seriously interfere with the proper air delivery. all work on the building was stopped, as the building was not being constructed in accordance with the plans on file, being a violation of Sec. 232, from which I previously quoted.

On the 8th inst. the architect came in to explain how the mistake had been made and signed a written statement that he would tear out the ducts and have them installed as per approved plans. The "stop order" was then removed.

On the 17th another inspection was made and the report is: "Alterations nearly completed; work being done according to plans."

Then on the 13th is found a final notation by the inspector that the work is completed and license recommended.

Now, if you will return to illustration, Figure 1, which is the front of this card, you will note that on June 18 application for license was approved. This completes the record for that building from the time the plan was approved on November 27, 1912, until the theatre was licensed to operate on June 18, 1913. The plan can now be removed from the files and stored in the vault or destroyed. The plan record we keep in our live file for a year at least for record and comparison with our observations of the operation of the system installed.

Now, you can see that the operation of such a system prevents the granting of a permit unless the plans show a system or method of ventilation that will comply with the ordinances. No deviation from these plans is possible during the erection of the building without our consent. And, finally, no license to operate a theatre can be obtained without our approval. The results obtained by handling the work in this manner are very satisfactory.

At the time we began, June 17, 1912, there were 526 theatres in Chicago all told. Of these eleven were properly ventilated. On July 1, 1913, our canvass shows that 131 new theatres have been built, every one equipped with a mechanical system of ventilation.

The next step in organization was to design an inspection record card for existing theatres to be used for recording tests of air samples and a description of the method of ventilation in use. This I show you on Figure 3. At the top of this card space is allotted for the street number and name of the theatre, with the date on which the first inspection was made. Beneath

NO. AND STREET 2829 Milwaukee Ave. NAME OF THEATRE Enterprise 3/10/13

DATE	PRIMARY SENSE IMPRESSIONS	DUST	TEMP. WET PSY-DRY		R. H. %	CO2	CULTURES	PLACE OF OBSERVATIONS	OUTSIDE CONDITIONS BARO. TEMP. R. H. % WIND
3/21/13	Good		60°	66°	71%	12 / 12	4 colonies 5 minutes	Front & Rear	29.42 21° 64% W.26
4/5/13	Good		61°	68°	67%	16.5 / 16.	12 colonies 10 minutes	" " "	29.44 41° 60% NE.9

ORIGIN Disc CLASS IVC STORIES 1 CELLAR ✓ BSMT. —— YEAR BUILT 1912 INSPECTOR Dieboldt

OWNER OF BUILDING Henry Luthie ADDRESS 2833 Milwaukee Ave. SEATING CAPACITY MAIN FLOOR 299 BALCONY— GALLERY—

OWNER OF THEATRE Robt. Schwalbe & Ed. Noeppe 2829 Milwaukee Ave.

MGR. OF THEATRE " " " " " SHOWS NO. DAILY 7:00 TIME to 10:30 P.M.

SYSTEM OF HEATING AND VENTILATION Steam - Ideal 5.25-6 4 stacks Vento. CIR. FANS 0

Blast system side wall introduction VENT. SYSTEM IN USE Continuously

FAN 42" ABC. Disc R. P. M. 350 HOUSING HEIGHT —— WIDTH

INLET 42" OUTLET 42" FAN WHEEL DIAM. 42" TYPE Disc MOTOR 3 HP TYPE Induction

INTAKES DIMENSIONS 18" x 50" LOCATION wall lobby MAIN DUCT DIMENSIONS 24" x 42" down to 8" x 80" LENGTH

DISTRIBUTORS NO. 5 SIZE 8" x 24" LENGTH 10' LOCATION Wall REGISTERS NO. 5 SIZE 12" x 20" LOCATION side wall.

OUTLETS NO. 1, 2, 3, 4 SIZE 8x12, 12x14, 12x24, 36 diam LOCATION wall ceiling line, " floor, " ", roof TYPE Registers, ", ", " ANEM. READ average reading at intake register 1030'

TOTAL AIR DELIVERED 6000 CFM. DRESSING ROOMS 2 under stage

TOILETS 1 W. C. under stage

H-S.-8 888 DEP'T OF HEALTH, CHICAGO PLAN APPROVED 4/12/09

FIG. 3.

this you will note the space for dates of subsequent inspections, with the results of each. This inspection covers primary sense impression, dust, temperature, relative humidity, carbon dioxide content and cultures. Further, we have a space for noting the place or places in which observations were made or samples taken, and another space for recording outside weather conditions.

Under primary sense impression the inspector is instructed to note the condition of the air as it affects his sense upon first entering the theatre, to observe whether it is close, stuffy, hot, dusty or humid, and if there are any objectionable odors, the intention being to determine if possible to what extent the senses act as a safeguard in detecting vitiated air and whether the effect on the senses bears any direct relation to our laboratory analysis of the air samples taken.

In making determinations of dust we have found it impracticable to use our apparatus in theatres while the show is in progress. So the inspector simply observes deposits of dust on the seats, chair railings and other objects. The temperature is taken in at least four locations in different parts of the house. Wet and dry bulb temperatures are taken by the Sling psychrometer and the relative humidity taken from Bulletin 235 of the United States Department of Agriculture. Cultures are made by exposing the ordinary Petrie dish containing a standard culture media of agar-agar and peptone. These plates are exposed, say for five minutes, and incubated for forty-eight hours at 38 deg. C. The places where the observations are made are noted in the next column and the outside weather conditions added by the clerk of the office from our weekly report from the Weather Bureau. This part of the record is what might be called the results of a physical inspection. It is made in this manner and with considerable trouble and detail, for the reason given at the beginning of the paper, namely, that a careful analysis of the data obtained in this way covering a large number of theatres and extending over considerable periods of time may be of value in determining what are the harmful constituents in improperly ventilated theatres.

Figure 4 is the reverse of our other record card just shown. Here the inspector makes a drawing to scale in both plan and elevation, if necessary, which, taken in conjunction with the data

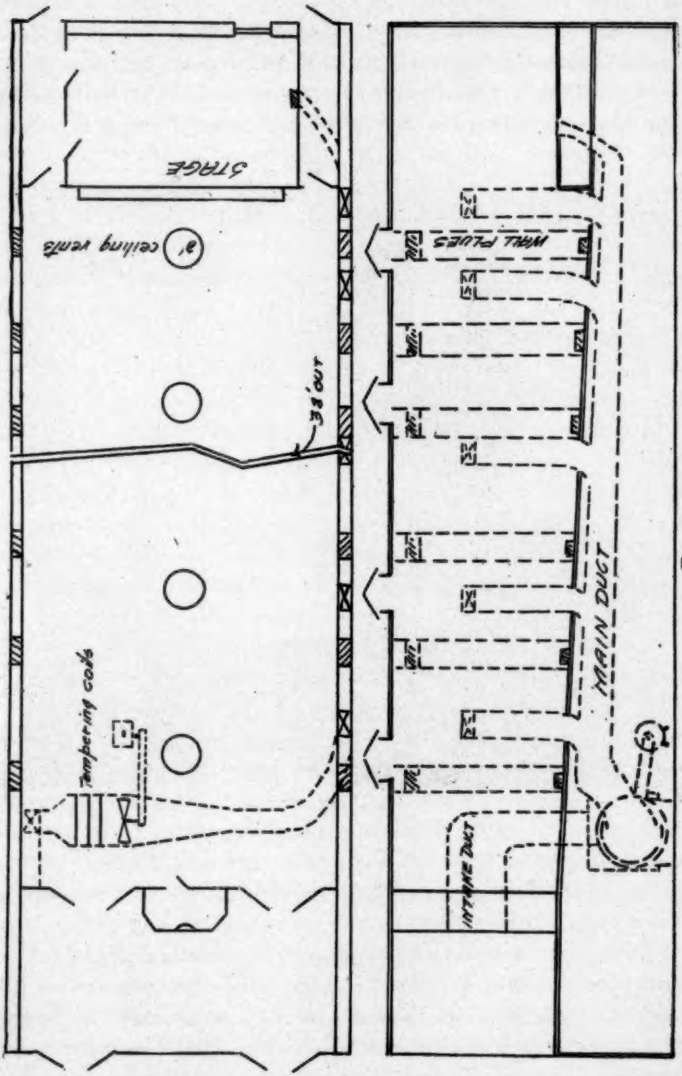

STAGE
8' ceiling vents
38' OUT
Tempering coils
WALL FLUES
MAIN DUCT
INTAKE DUCT

FIG. 4.

on the front of the card, gives a very complete and accurate record.

We use two white porcelain evaporating dishes. One of these was exposed on the fire escape of the City Hall on a level with the seventh floor for six hours; this is compared with the other that is photographed by the side of a clean dish of the same

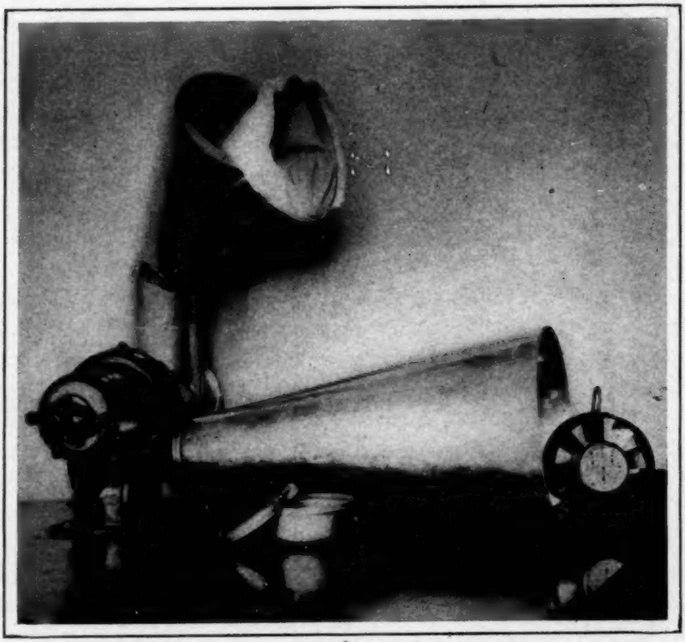


FIG. 5.

kind to show the deposit of dirt—mostly soot—that occurs in this short time.

The inspector uses a konoscope, an instrument designed by Prof. John Aitken for determining the amount of dust in the air by a dust count of the particles in a given quantity of air. Our experience with this instrument has not been entirely satisfactory, owing to the element of individual error to which it is liable.

We have devised a machine (Fig. 5) for making a more accurate determination of the amount of dust in a given quantity

of air. It consists of a small sirocco fan, the inlet of which is connected with a horn in which are suspended two fine mesh cloth bags, one inside the other. In the outlet is an anemometer for measuring the amount of air which passes through the apparatus. The cloth bags are first dried to a point where the moisture is entirely driven off and the weight becomes constant and this weight is recorded. After drawing perhaps 10,000 cubic feet of air through the apparatus the bags are carefully removed, dried again to concentrate, and the increase denotes the amount of dust in the air which passed through the apparatus. Our experiments with this machine were not entirely satisfactory, owing to the fact that different kinds of dust vary widely in weight. For instance, air samples taken in front and behind an air washer gave rather startling results, the weight of the dust in the air after it passed through the washer and tempering coils being seven times as great as at the intake. After considerable study we found that this was due to the fact that after the air had passed through the tempering coils it took up enough rust to increase the weight to an enormous extent, and while the number of dust particles was very materially reduced by the washer the total weight of the small amount remaining was seven times greater than before it passed through the washer and coils owing to the different composition of the dust. So we devised a method of counting the dust particles, which we call our Dust Machine No. 2, shown in Figure 6.

This consists of a gas meter as shown by the slide, on the inlet of which is attached a sugar filter. This filter consists of a glass receptacle with a fine mesh screen, on which is placed twenty-five grams of pure, dust-free granulated sugar. To the outlet of the motor is attached an exhaust fan capable of maintaining a pressure of about four ounces. The air is drawn through this sugar filter and measured by the gas meter, from ten to fifty cubic feet being used, according to the amount of dust in the air to be analyzed. The filter is removed and the sugar dissolved in 100 c. c. of distilled water. The next step is to place a measured quantity of this dirt in suspension on a glass slide and to count with the microscope the number of dust particles. For this we use the Sedgwick-Rafter counting scale. This consists of a glass cell with a raised box-like portion which holds exactly one cubic centimeter of the solution. A ruled ocular is

also provided, the rulings being so arranged that each square gives an equivalent area of one millimeter on the slide. Counting, therefore, the number of dust particles on these squares over different areas in the field gives a very close approximation of the number of dust particles in one cubic centimeter of the solution. Noting from the dial of the gas meter the number of

FIG. 6.

cubic feet of air that have passed through the filter and correcting this for the dilution of the mixture, we can readily determine the dust particles in a cubic foot of air, that is, the number of dust particles that are visible with the magnification of about 300 diameters.

Samples taken on street cars, in theatres, on the tops of skyscrapers, at the street level, on the decks of steamers crossing the lake and in various other localities, and in all conditions of weather, have given us a fairly accurate idea of the amount of

dust that should be found in pure air and what a fair standard should be.

For determining the relative humidity.—We used a Sling psychrometer for this work. The inspector wets the bulb and swings the instrument to promote evaporation and thus determines the wet bulb temperature.

For determining the amount of carbon dioxide.—The department has experimented with various methods of collecting air samples and has finally adopted one as being as convenient as any. The bottle is of 100 c. c. capacity, carefully washed and cleaned, with a rubber stopper. The pump consists of a rubber bulb with a double set of valves, with a tube leading to a reservoir, from which another tube conveys the air into the bottle. The inspector is instructed to hold the bulb as far from his face or any source of contamination as possible. The reservoir is pumped full of air by compressing the outlet tube with the thumb on the neck of the bottle. Then the thumb is released and the air in the reservoir allowed to displace the air in the bottle. This is repeated three times or more until the inspector is absolutely sure that all of the reservoir air, both in the bottle and in the apparatus, has been replaced by the air in the room. The tube is now withdrawn, the bottle quickly corked and a numbered sticker affixed and the bottle taken to the laboratory for analysis.

We use the Peterson-Palmquist apparatus for determining the amount of CO_2. The operation of this machine is rather complicated and an explanation difficult, so I will not attempt it at this time.

Petrie dishes are used for determining the relative number of bacteria in the air.

Our method of taking anemometer readings is to divide the face of the registers into a number of squares, but beyond that I will not stop to describe them at this time.

Now, returning to Figure 3, we can make a brief analysis of the information obtained. The primary sense impression in this case was good. There seems to be no notation on this record as to the amount of dust. The wet bulb temperature was 60, the dry bulb 66, giving us a relative humidity of 71 per cent. The two samples of air gave a CO_2 analysis of twelve parts

each and the culture dishes exposed for five minutes gave four colonies and for ten minutes twelve colonies.

These observations were made in the front and rear of this theatre when the outside weather conditions were as follows: Barometric pressure, 29.42; temperature, 21 deg. F.; relative humidity, 64 per cent.; the wind was in the west, blowing at the rate of 26 miles an hour.

Another inspection on April 5 gave practically the same results, except that the carbon dioxides contained were somewhat higher.

These physical inspections, as I have called them, should now be compared with the mechanical equipment of this theatre. We find this a theatre containing 299 seats. Shows are given continuously from 7:00 to 10:30 p. m. The ventilating equipment consists of a 42-inch American Blower Company's disc fan operating at 350 r. p. m., driving the air through four stacks of Vento through an intake in the lobby wall and distributing it through five side-wall supply registers, 12 x 20″ each, at an average velocity of 1,030 feet per minute, the total amount of air delivered being 6,000 c. f. m., or 20 c. f. m. per person. So we find in a theatre in this instance which is kept clean, where 20 c. f. m. per person is being supplied at a high velocity, an almost ideal condition as to cultures CO_2, content, temperature, etc. Such a record we have of 600 theatres in Chicago, and it appears to me that a large number of these observations covering considerable periods of time will be of considerable value in helping to determine what are the essentials of good ventilation and what are the deleterious constituents or effects of respired air. Some have questioned whether the amount of work required to make a record of this kind is justified by the result. Personally I must say that it is. Not only as a matter of scientific investigation but as a complete record for the routine work of the department.

It is not an uncommon occurrence for theatre owners or managers to come into our office, after receiving notice, to tell us what they have provided and what extremely well-ventilated theatres they are operating. When we produce the record which I have just described and tell them facts, not only as to the observations made, but details of construction and of operation

NO. AND STREET 1233 So. Halsted St DATE OF INSPECTION Feb 8 1913

BUILDING Frame ✓ Brick STORIES 3 Number Basement ✓ Cellar Attic OCCUPIED BY old Theater Families Stores INSPECTOR Gillespie

OWNER B Schwartz AGENT Gador Nathin Lessee

ADDRESS ADDRESS 3044 W Jackson Boul

ORIGIN Complaint No. H to H Restaurant Bakery Workshop Misc. ✓ Comm'r Ch. Ins. TENANT J.B. Grossman

NOTICE to Owner—Agent Tenant—Plumber ✓ 10 Days limit FEB 14 1913 Issued Extended to By whom 1125 Newberry Ave Sued Posted

Provide adequate ventilation, clean floors and maintain same in a sanitary condition

Has one exhaust fan 18" No other mechanical ventilation
Temp 74° Air sample taken. 292 seats see theater card
3/6/13 Nothing done. Called at Grossman home left word
to get started on work. Made drawing
3/24/13 Inspection made, full house Details on
theater card

DEPARTMENT OF HEALTH, BUREAU OF SANITARY INSPECTION, CHICAGO.

Fig. 7.

about their own theatres of which they themselves were not aware, the impression made is sometimes very startling.

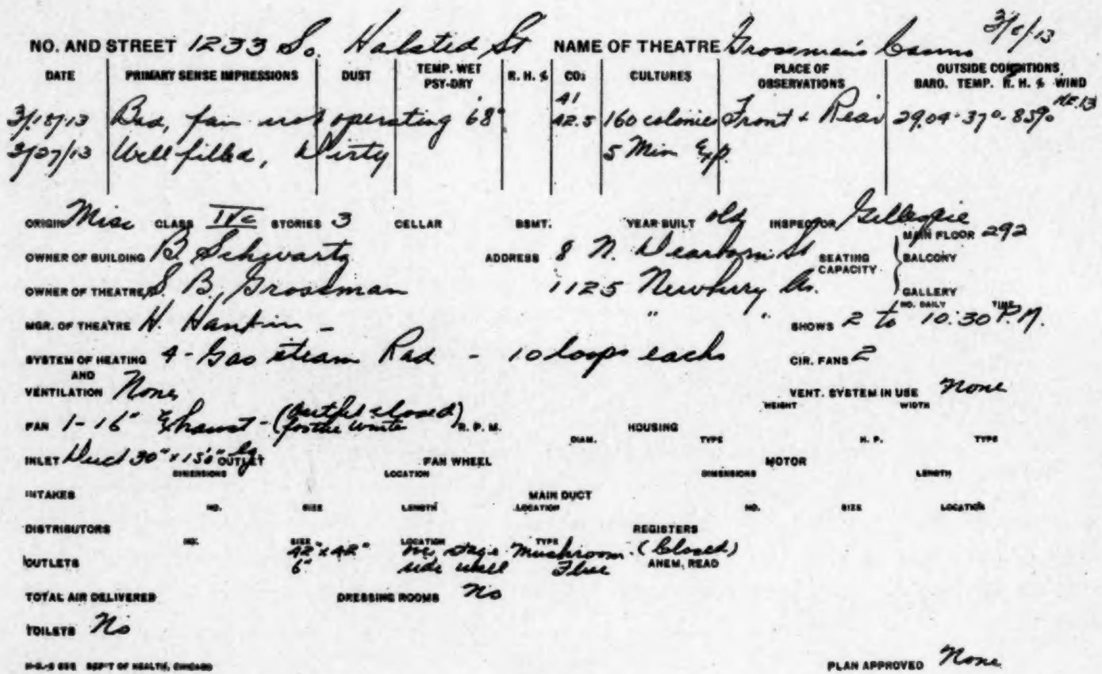
Figure 7 is our regular complaint card. When an inspection has been made and the theatre found to be inadequately ventilated, a notice is written by the inspector on this card, which is turned in to the notice clerk and a typewritten notice issued.

I will describe one of the old theatres which is a reconstructed store building, and it may be taken as a type of this class of buildings. It is practically a closed box. No method whatever is provided for supplying fresh air except what leaks through the front and rear doors. An old exhaust fan has at some time been installed in the rear wall, but the opening is sheeted up and the fan inoperative. The walls are streaked with water leaking from the floor above. It is also supplied with deodorizing machines which the inspectors call "perfumers." These are the same type as are used for destroying the odor in toilet compartments.

Figure 8 will show the record card of this theatre. On March 18 inspection was made. The inspector reports primary sense impression bad; fan not running; temperature was 68; relative humidity does not appear to have been taken; carbon dioxide analysis gave 41 and 42.5 parts, respectively, and 160 colonies, on a five-minute outer plate exposure. This is not unusual but a rather typical finding in those old, unsanitary theatres. Compare this record now with the one we have just been discussing, of the Milwaukee Avenue theatre (Fig. 3), where there are twelve parts of carbon dioxide and where the plate cultures gave only four to six colonies, respectively.

Figure 9 is a card of the Milwaukee Avenue theatre. Observe the notations under the "Physical Inspection." No ventilation whatever; primary sense impression is very bad. The place is dusty. Relative humidity from 42 to 60. Cultures taken at various times give as high as 196 colonies, some of which show in a carbon dioxide analysis of over 70 parts. Note on this record that the ventilating equipment was installed in March, supplying 20 c. f. m. per person. The carbon dioxide analysis and the number of colonies by plate culture immediately fall to the required standard.

In the case of the Palace Theatre it has a large duct for the fresh air supply from a Zellwager fan. The air in this instance



NO. AND STREET 1233 So. Halsted St NAME OF THEATRE Grossman's Casino 3/6/13

DATE	PRIMARY SENSE IMPRESSIONS	DUST	TEMP. WET PSY-DRY	R. H. %	CO_2	CULTURES	PLACE OF OBSERVATIONS	OUTSIDE CONDITIONS BARO. TEMP. R. H. % WIND
3/18/13	Bad, fan not operating		68°		41	160 colonies	Front & Rear	29.04 · 37° · 85% NE 13
3/27/13	Well filled, Dirty				42.5	5 Min Exp		

ORIGIN Misc CLASS IVc STORIES 3 CELLAR BSMT. YEAR BUILT old INSPECTOR Gillespie

OWNER OF BUILDING B. Schwartz ADDRESS 8 N. Dearborn St SEATING CAPACITY MAIN FLOOR 292 BALCONY GALLERY

OWNER OF THEATRE S. B. Grossman 1125 Newbury Av.

MGR. OF THEATRE H. Hankin – " " SHOWS NO. DAILY TIME 2 to 10:30 P.M.

SYSTEM OF HEATING AND VENTILATION 4 - Gas steam Rad – 10 loops each CIR. FANS 2

None VENT. SYSTEM IN USE None HEIGHT WIDTH

FAN 1-16" Exhaust – (outlet closed) (for the winter) R. P. M. DIAM. HOUSING TYPE H. P. TYPE

INLET Duct 30" × 15" DIMENSIONS OUTLET FAN WHEEL LOCATION MOTOR DIMENSIONS LENGTH

INTAKES NO. SIZE LENGTH MAIN DUCT LOCATION NO. SIZE LOCATION

DISTRIBUTORS NO. SIZE LOCATION TYPE REGISTERS

OUTLETS 42" × 42" 6" Mr. stage side wall Mushroom Flue (Closed) ANEM. READ

TOTAL AIR DELIVERED DRESSING ROOMS No

TOILETS No

H-G-5 888 DEP'T OF HEALTH, CHICAGO PLAN APPROVED None

Fig. 8.

NO. AND STREET 764 Milwaukee Ave. NAME OF THEATRE Eagle 10/22/12

DATE	PRIMARY SENSE IMPRESSIONS	DUST	TEMP. WET PSY-DRY	R. H. %	CO_2	CULTURES		PLACE OF OBSERVATIONS	OUTSIDE CONDITIONS BARO.	TEMP.	R. H. %	WIND
3-7-13	Bad 8 PM	Yes	55 - 68	42	65 70	181	196	Front & Rear	29.04	37	85	NE.13
3-27-13	Dirty-House full	Some	53 - 70	30	46 12	88	104	" "	29.40	30	60	SW.11
5-6-13	Clean " "	No	60 - 70	60	14	16	8	" "	29.40	48	54	NE.4

ORIGIN Misc. CLASS IV STORIES 3 CELLAR — BSMT. — YEAR BUILT 1909 INSPECTOR Diebold

OWNER OF BUILDING Christ Polandson ADDRESS 527 N. California Ave. SEATING CAPACITY MAIN FLOOR 292 BALCONY — GALLERY —

OWNER OF THEATRE " " " "

MGR. OF THEATRE " " " "

SYSTEM OF HEATING AND VENTILATION Steam K.M.C. S 60 Modern None (5/1/13 - 3 - #2 Gariner installed) SHOWS NO. DAILY 5PM TO TIME 11PM

CIR. FANS 3

FAN See amended drawing R. P. M. VENT. SYSTEM IN USE Continuously HEIGHT WIDTH

INLET 3'6" X 23" DIMENSIONS OUTLET 14" X 14" LOCATION FAN WHEEL 15" DIAM. HOUSING Sirocco TYPE DIMENSIONS MOTOR 3/4 H.P. A.C. TYPE LENGTH

INTAKES —

DISTRIBUTORS — NO. SIZE LENGTH MAIN DUCT — LOCATION

OUTLETS NO. 1 1 1 SIZE 42" X 42" 36" DIA 12" X 24" LOCATION Roof under stage TYPE REGISTERS NO. SIZE LOCATION Same as outlets

TOTAL AIR DELIVERED 6000 C.F.M. DRESSING ROOMS — ANEM. READ Av. Velocity 1200 at supply

TOILETS 2 W.C. with vent compartments by outside windows

B-O-4 500 DEP'T OF HEALTH, CHICAGO

PLAN APPROVED 4/16/13

FIG. 9.

is taken through the sidewalk grating before passing through the combined fan and air washer and delivered into a Plenum chamber. This theatre has fresh air supply registers under each seat (see Fig. 10), with a stovepipe stopper plate underneath to regulate the air supply (see Fig. 11). The exhaust registers are at the rear under the balcony.

A plate culture taken of this theatre when the house was full showed 14 colonies; another taken nearer the aisle showed 17 colonies. There is one interesting feature in this case which repeated tests have demonstrated to my satisfaction, and that is a fresh air intake located in the sidewalk will give a larger dust or bacteria count, even where an air washer is used, than an intake located 12 or 15 feet above the sidewalk level without an air washer.

In another theatre which is heated and ventilated by a combined fan and furnace equipment the fresh air is supplied through the two registers on either side of the stage in the proscenium wall. This is a 300-seat house and 20 c. f. m. per person is supplied, but owing to the fact that the air is introduced at a temperature of 100 degrees or more in cold weather it rises directly to the ceiling, passes forward and out at the other end of the theatre through registers, which leaves the air at the breathing line largely unchanged.

Air samples taken in this theatre gave a carbon dioxide analysis of as high as 36 parts, whereas if the amount of air supplied was properly distributed in the breathing zone the carbon dioxide would not rise above twelve parts. This illustrates two facts: It is very difficult to properly ventilate a theatre with the air at high temperatures; also, that the introduction of air for ventilation at more than one end of a room is necessary for proper distribution.

In another theatre equipped with a floor introduction method of ventilation the ducts were found somewhat dirty and the theatre not maintained in a sanitary condition. Notwithstanding these facts, with 25 c. f. m. per person being constantly introduced, we obtained 27 colonies on a 10-minute plate exposure, which would mean 13½ colonies for our standard five-minute culture.

In another 300-seat theatre ventilated with a mechanical system, which was very popular, on account of its price, the air

FIG. 10.

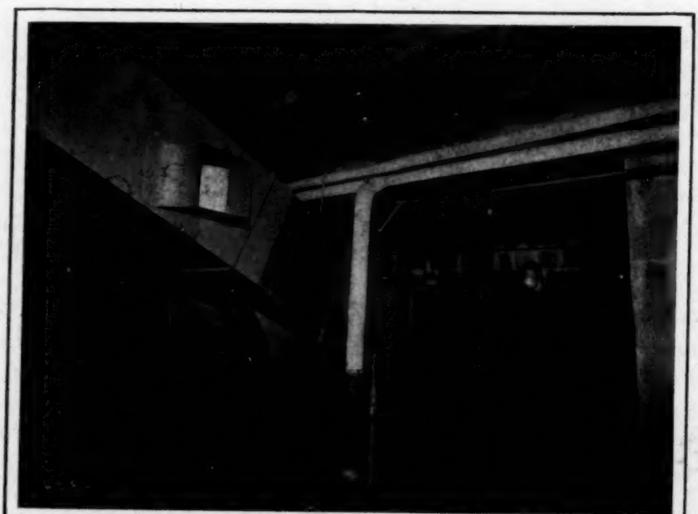


FIG. 11.

supply in this instance was obtained through one-inch openings in the side walls, about thirteen of these openings on each side of the theatre.

In the fan room of this theatre a No. 30 Buffalo Forge Company's steel plate exhauster, operated by a 5 h. p. motor, draws the air from the roof through a 12-inch circular intake. The outlet of the fan is cut down to 10 inches in diameter and the air is passed into a cooling and perfuming device. The outlet from this device is an 8-inch pipe which after passing through the tile wall divides into 4-inch pipes, one running down each side of the theatre, from which the one-inch outlets distribute the air. Upon my telling the contractor who installed this device that it would not deliver over 20 per cent. of the air required by the ordinance he scratched his head in a thoughtful way and decided he would have to put a 10 h. p. motor on the fan instead of the 5 h. p. which he was using.

We took a culture plate in a street car where the air for ventilating is drawn in through unprotected openings in the floor. This plate showed 420 colonies on a five-minute exposure; another taken on the same car showed 386 colonies. Our test dust counts taken on this same car gave 16,000,000 particles per cubic foot of air. The dust counts on the roof of the City Hall in fair weather gave 485,000 dust particles per cubic foot. On a boat crossing Lake Michigan we obtained 9,000 dust particles. I give you these figures for comparison.

I have another plate exposed for 10 minutes on the hurricane deck of the *Theodore Roosevelt* while crossing from Chicago to Michigan City. It shows one colony.

I have two other interesting plates—the first taken at the fresh air intake of the ventilating equipment of the Otis Building in Chicago before the air passed through the washer. This intake is located at the level of the second floor and is not well protected. It gave us 57 colonies. The other was taken at the inlet of the fan after the air had passed through the washer and gave 4 colonies.

In conclusion I would say that, while the data collected by the Ventilation Division is by no means complete and while we would not be justified in forming positive conclusions from the short time we have been making these observations, still there are certain conclusions which are strongly indicated and which I

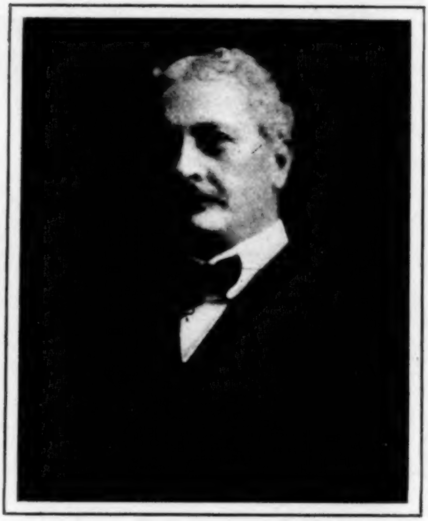
will give you, and which future observations will either verify or disprove.

First: Twenty-five c. f. m. per person is the minimum amount of air which should be required for adequate ventilation of theatres. Its introduction presents no serious mechanical difficulties and the equipment required can be installed and operated without unreasonable expense. This conclusion is based upon an analysis of 607 inspections in as many theatres during the past winter. It requires that amount of air to take care of objectionable odors which arise, to keep the carbon dioxide down to the point required by the ordinance and to keep the number of colonies on our culture plates below fifteen with a five-minute exposure, and in the present state of our knowledge we certainly should require no less.

Second: The amount of moisture in the air in theatres practically never becomes low enough to require artificial humidifying, but an efficient air washer is absolutely essential where the intake is liable to dust contamination.

Third: A temperature ranging from 55 to 75 degrees is neither uncomfortable nor injurious to health.

Fourth: The number of dust particles is inversely proportioned to the amount of fresh air supplied.



WILTSIE F. WOLFE.

Wiltsie F. Wolfe was the third of our Presidents to depart this life, which event occurred December 4, 1913, at his home in Atlantic City, N. J., in the 59th year of his age.

Mr. Wolfe was one of the pioneers of the heating and ventilating trade.

He first saw the light of day at Troy, N. Y., which at that time was practically the center of the stove and furnace industry of this country.

Mr. Wolfe was particularly interested in school warming and ventilating, and was president of the Wolfe Warming and Ventilating Company, who equipped a large number of the schools throughout the New England States with the Wolfe Heating and Ventilating Apparatus.

Mr. Wolfe was one of the charter members of the Society, and its President in 1898, and up to the time of his decease took an active part in the proceedings of the Society.

After the death of his father he became president of the Fowler & Wolfe Manufacturing Co., and from that time he was actively identified with that company.

In Memoriam

	Joined the Society.	Died.
L. H. Hart, New York	Sept. 1894	Jan. 26, 1897
James W. Gifford, Attleboro, Mass.	Jan. 1898	July 26, 1899
William McMannis, New York	Sept. 1894	Jan. 19, 1901
Charles F. Tay, San Francisco, Cal.	Jan. 1896	Sept. 8, 1901
Arthur H. Fowler, Philadelphia, Pa.	Jan. 1897	June 3, 1903
Stephen G. Clark, New York	Dec. 1902	Feb. 3, 1904
Charles M. Wilkes, Chicago, Ill.	Jan. 1897	Jan. 7, 1905
James Curran, New York	Dec. 1901	Oct. 27, 1905
Herbert W. Nowell, New York	June 1904	Mar. 25, 1905
Enoch Rutzler, New York	July 1901	Feb. 29, 1908
Harry J. Ott, Chicago, Ill.	Dec. 1906	Sept. 25, 1908
Thomas J. Waters, Chicago, Ill.	Sept. 1894	Feb. 25, 1909
Max J. Mulhall, New York	June 1909	July 30, 1909
Walter B. Pelton, Dorchester, Mass.	June 1910	Nov. 2, 1910
R. Barnard Talcott, Denver, Colo.	June 1899	Dec. 4, 1910
William H. Bryan, St. Louis, Mo.	July 1898	Dec. 8, 1910
James R. Wade, St. Louis, Mo.	Dec. 1909	Mar. 9, 1911
James Mackay, Chicago, Ill.	Sept. 1894	July 18, 1911
Warren S. Johnson, Milwaukee, Wis.	Jan. 1906	Dec. 5, 1911
W. C. Bryant, Holton, Kans.	Jan. 1901	April 6, 1912
H. A. Joslin, Boston, Mass.	Jan. 1896	Oct. 3, 1912
Andrew Harvey, Detroit, Mich.	Jan. 1896	Oct. 9, 1912
N. P. Andrus, Brooklyn, N. Y.	Sept. 1894	Jan. 13, 1913
J. A. Payne, Jersey City, N. J.	Sept. 1894	Mar. 3, 1913
J. S. Billings, New York	Jan. 1896	Mar. 10, 1913
Wiltsie F. Wolfe, Philadelphia, Pa.	Sept. 1894	Dec. 4, 1913
R. C. Clarkson, Philadelphia, Pa.	Sept. 1894	Dec. 26, 1913

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